DO YOU KNOW?

How to make a crystal rock garden? How to make soap? What an electrolyte is?

DO YOU KNOW?

The principle of the phonograph? The reasons for the behavior of light? The difference between opened, closed and short circuits? The relationship between electricity and magnetism?

DO YOU KNOW?

How to bisect an earthworm? How a flower reproduces? Where bacteria flourish? How to culture a mold?

DO YOU KNOW?

How the slant of the sun's rays affect the temperature? How to construct a nephoscope? How to make an anemometer?

DO YOU KNOW?

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INTRODUCTION

Boys and girls who have manipulated wires, heated test tubes, and peered through the microscope know the excitement of experimenting in the sciences. This book is written for them and for all other young people interested in exploring some of nature's basic laws through the experimental process.

There are more than 150 experiments presented here, each with its list of necessary materials and step-by-step instructions. With patience and care, with scrupulous attention to all safety precautions, students should be able to follow these instructions to a successful conclusion, whether it is solving an algebraic puzzle or building a light switch.

The fields covered in this book are chemistry, physics, biology, weather, and numbers. The experiments—designed for grades six to nine or ten—range from easy to challenging. Our goal has been to reach not only those who are firmly committed to a science career, but future poets and presidents, who may be curious about what a cloud is or how plants make their food. We think that one of the best ways to learn about such things is through these experiments, where established scientific truths can be satisfyingly demonstrated—again, and again, and again.

Watson Davis, Director
Science Service

ACKNOWLEDGMENTS

Much of the material in this book is based on classic experiments. In writing the present versions of these experiments, I relied on many people for their vital assistance. I would like to thank, in particular:

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Judith Viorst

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PART 1
CHEMISTRY

Chemistry is the science that makes sense of flashlight batteries and nylon stockings, mayonnaise and toothpaste. It is the science—as the dictionary says—that describes the composition of substances and explains the various changes which they undergo.

There are good scientific reasons why iron rusts and rain puddles disappear, and why the same three elements can combine to produce substances as different as sugar and vinegar. These reasons have been discovered over the centuries by patient and inquisitive people who were not content to breathe the air without wondering what it was made of.

The following experiments will demonstrate some of these basic laws of chemistry. Many of the chemicals needed for this work can be taken from your kitchen or bathroom shelf; others must be purchased from a pharmacy or a laboratory supply house. Collect bottles of every size and shape, wash them well, and use them for storing all storable chemicals. Be sure to label each container clearly and correctly.

■ SAFETY RULES

You will find that many of the experiments contain words of warning and rules for safety. They are not there because we are particularly nervous, but because we regard them as essential. In addition to individual safety rules given for a particular experiment, we present these general rules that you must follow:

1. Read an experiment through before beginning work on it.
2. Provide adequate ventilation and have an extinguisher handy to put out fires.
3. Inhale vapors cautiously.
4. Keep your face away from materials being heated in a test tube. Hold the tube away from you when heating or shaking.
5. Always wear a rubber apron when you work.
6. Wear goggles when working with heat, with acids or lye, or with any other potentially hazardous materials.
7. Heat materials contained in a flask or test tube clamped to a ring stand by passing the burner back and forth under the container. Don't ever let the flame fix continuously on one point at the bottom of the test tube.
8. Work with small quantities, as directed.
9. Be very careful when working with acids. They can cause serious burns.
10. Keep all containers and equipment clean and keep your working area neat.
11. Never mix chemicals together any which way just to see what happens. You may not be around to find out.

Some of the experiments included in this section are definitely not intended for home use. These are labeled **(with qualified adult supervision only!)**, and must be done at school with a teacher or through a science club with a club sponsor. All experiments requiring a Bunsen burner, or strong acids, or involving serious hazard if performed incorrectly come under this category.

Now that we have completed all our warnings, we want to add a final suggestion—enjoy yourself. Strange as it may seem, being sensible does not make it impossible to have fun.

MOLECULES

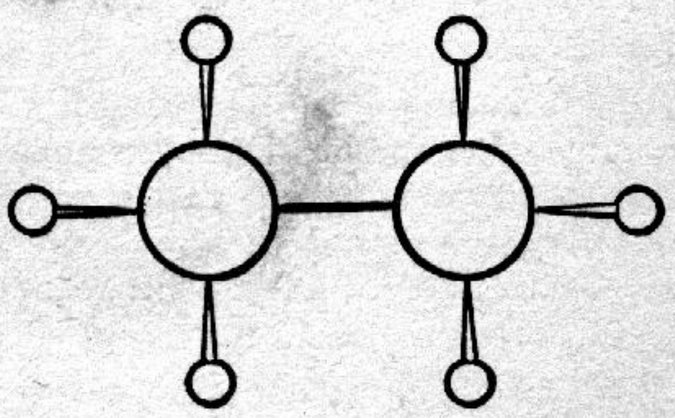
■ MOLECULE MODELS

Purpose

All matter is composed of molecules. Molecules are composed of atoms. The molecules of an element (like iron or oxygen) are made up of identical atoms. The molecules of a compound (like water or sugar), which is a combination of elements, are made up of different types of atoms. The types and the arrangements of atoms in a molecule determine the properties of a compound. For instance, sugar is made up of carbon, hydrogen, and oxygen; so is vinegar. But sugar and vinegar are quite different compounds because a vinegar molecule has 2 carbon atoms, 4 hydrogen atoms, and 2 oxygen atoms; while a sugar molecule has 12 carbon atoms, 22 hydrogen atoms, and 11 oxygen atoms. By making models of the molecules that comprise a few compounds, you can learn some of the ways in which atoms combine.

Apparatus

red clay
white clay
black clay
toothpicks



Steps

First prepare the atom molecules.

1. Use the black clay to make three round balls about 1½ inches in diameter.

2. Use the red clay to make three round balls slightly smaller than the black ones.

3. Use the white clay to make 14 tiny white balls.

4. Now fix in your mind what your apparatus represents: The black balls are carbon atoms, the red balls are oxygen atoms, and the white balls are hydrogen atoms. The toothpicks represent chemical bonds, which are the "hands" atoms use to hold on to each other. Each of these atoms has a definite number of bonds—four for carbon, two for oxygen, and one for hydrogen.

Now begin molecule making.

5. Push a toothpick part way into the top of a carbon atom. Push a second toothpick into the bottom, a third into the left side, and a fourth into the right. Your carbon atom now has its four bonds.

6. Attach a hydrogen atom to the end of each carbon bond. You now have the molecule methane, whose chemical designation is CH_4.

7. Prepare a second carbon atom as you did in step 5. Prepare a third, but do not push a toothpick into its left side. Instead, connect the two carbon atoms side by side by pushing the right toothpick of the second carbon atom part way into the left side of the third. (This toothpick actually represents both the right bond of the second carbon atom and the left bond of the third.)

8. Attach hydrogen atoms to the six protruding carbon bonds. You now have the molecule ethane, whose chemical designation is C_2H_6.

9. Set up the following from left to right: a hydrogen atom, an oxygen atom, and another hydrogen atom. Connect them side by side with two bonds, so that your model looks like this: H—O—H. You now have a molecule whose chemical designation is H_2O. We'll let you figure out what the substance is.

10. Set up the following from left to right: a hydrogen atom, an oxygen atom, another oxygen atom, and a second hydrogen atom. Link them side by side with chemical bonds like this: H—O—O—H. This is the hydrogen peroxide molecule, H_2O_2.

Observations

Because hydrogen has only one bond, it can connect at only one point with another atom. Oxygen, with its two bonds,

can connect at two points, as in the water molecule and the hydrogen peroxide molecule. Carbon can make a four-way connection, as demonstrated in the methane and ethane molecules.

■ CHEMICAL CHANGE

EXPERIMENT 1

Purpose

Materials change, usually, in one of two ways—physically or chemically. In a physical change the size, shape, or state of a substance may be altered, but the molecules remain the same. In a chemical change, however, new molecules result and new substances are formed. There are four broad categories of chemical change, or reaction: combination, decomposition, simple replacement, and double replacement. Scientists describe such changes by a shorthand method—the chemical equation. In this experiment we will learn the definitions of these four categories of chemical changes and examine the equations that describe them.

Apparatus

pencil and paper

Steps

1. When two or more elements or compounds combine to form a single compound, this chemical reaction is called combination. For instance, the element carbon combines with oxygen gas to form carbon dioxide. The symbol for carbon is C, the symbol for oxygen gas is O_2 (two oxygen atoms), the formula for carbon dioxide is CO_2. The equation for this reaction is $C + O_2 \rightarrow CO_2$. Write the equation for the combination of sulfur, S, and oxygen gas to form sulfur dioxide, SO_2.

2. Decomposition is the breakdown of a compound into simpler substances. Calcium carbonate, $CaCO_3$, decomposes into calcium oxide, CaO, and carbon dioxide. The equation is $CaCO_3 \rightarrow CaO + CO_2$. The compound sulfurous acid, H_2SO_3, decomposes into water and sulfur dioxide. Write the equation for this chemical change.

3. In simple replacement, an atom trades places with another kind of atom in a compound. Thus, when dilute sulfuric acid, H_2SO_4, is poured on zinc, Zn, the zinc replaces the hydrogen in the acid. The new substances are zinc sulfate and hydrogen gas (two hydrogen atoms). Write the equation.

4. Double replacement occurs when two atoms from two different compounds are interchanged. For instance, hydrochloric acid, HCl, and sodium hydroxide, NaOH, yield water and sodium chloride. Write the equation.

Observations

The four equations are: (1) $S + O_2 \rightarrow SO_2$; (2) $H_2SO_3 \rightarrow H_2O + SO_2$; (3) $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$; (4) $HCl + NaOH \rightarrow NaCl + H_2O$. Note that in each case the equation balances, that is, there are the same number of atoms on each side, although they are arranged differently. Often it is necessary to place a number, called a coefficient, in front of symbols and formulas to make an equation balance. For instance, the element magnesium, Mg, can combine with oxygen gas, O_2, to form a new substance, magnesium oxide, MgO. But you can't write $Mg + O_2 \rightarrow MgO$, for this is an unbalanced equation. And you can't write $Mg + O_2 \rightarrow MgO_2$, for MgO_2 is not the symbol for magnesium oxide. The balanced equation for this chemical reaction is $2Mg + O_2 \rightarrow 2MgO$. We have added the coefficient 2 where needed.

EXPERIMENT 2

Purpose

Chemical change by combination will be demonstrated.

Apparatus

stove
pliers or tongs
small piece of pure copper pot-cleaner

Steps

1. Light a burner, grasp the copper with the pliers, and hold it in the flame.

2. After several seconds remove the copper from the flame and examine it.

Observations

The copper combined with oxygen to produce copper oxide, which appears as a black coating on the copper. The symbol

for copper is Cu, oxygen gas (made up of two atoms of oxygen) is O_2, copper oxide is CuO. Thus two copper molecules plus the oxygen gas are needed for the reaction. The equation is $2Cu + O_2 \rightarrow 2CuO$.

EXPERIMENT 3

Purpose

Chemical change by decomposition will be demonstrated.

Apparatus

pot
sugar
stove

Steps

1. Put 1 teaspoon sugar in the pot.
2. Put the pot on the stove and heat it.
3. Continue the heat until you have a black mass where the sugar used to be.

Observations

Sugar is composed of three elements—carbon, oxygen, and hydrogen. By heating it you have decomposed it to the compound water, which leaves the sugar as water vapor, and the element carbon, the black mass in the pot. The symbol for sugar is $C_{12}H_{22}O_{11}$. The equation for this reaction is $C_{12}H_{22}O_{11} \rightarrow 12C + 11H_2O$.

EXPERIMENT 4

(With qualified adult supervision only!)

Purpose

Chemical change by simple replacement will be demonstrated.

Apparatus

¼ teaspoon copper sulfate (*Handle carefully—poison!*)
2 ounces water
glass
stirring rod
iron nail

Steps

1. Pour the water into the glass, add the copper sulfate and stir until it dissolves.
2. Dip the nail into the copper-sulfate solution and hold it there for a minute or so.
3. Remove the nail and examine it.

Observations

The iron and the copper have traded places—the iron has gone into solution to form iron sulfate, and the nail is covered with a copper coat. The equation is $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$.

EXPERIMENT 5

(With qualified adult supervision only!)

Purpose

Chemical change by double replacement will be demonstrated.

Apparatus

¼ teaspoon copper sulfate (*Handle carefully—poison!*)
¼ teaspoon barium chloride
4 ounces water
2 glasses
stirring rod

Steps

1. Fill each glass with 2 ounces water.
2. Dissolve the copper sulfate in one glass, the barium chloride in the other.
3. Mix the two solutions together. Set aside for a while and observe what happens.

Observations

A white substance forms and settles to the bottom. A blue solution remains. The white substance is barium sulfate; the blue solution is copper chloride. The sulfate and chloride have exchanged places. The equation for this chemical reaction is $CuSO_4 + BaCl_2 \rightarrow CuCl_2 + BaSO_4$.

SOLUTIONS AND PRECIPITATES

■ SOLUTIONS

Purpose

A mixture is a material made of elements or compounds or both. These substances are not chemically combined, however, and their composition may vary from mixture to mixture. There are non-uniform mixtures, like soil or rocks; and uniform mixtures, like homogeneous solutions. The experiments below will demonstrate some characteristics of solutions.

Apparatus

sugar
water
pot
teaspoon

EXPERIMENT 1

Steps

1. Pour ½ cup of water into the pot.
2. Add 1 spoonful of sugar to the water and stir until it dissolves.
3. Let the mixture stand for a while, then examine it.
4. Continue adding sugar, 1 teaspoon at a time, until no more dissolves, despite stirring and shaking.

Observations

A solution consists of a solvent and a solute, which remain mixed together even after long standing. A solvent is a material capable of dissolving solutes, which, of course, are materials that dissolve. In this experiment we have shown that the sugar-water mixture is a solution. The solvent, water, dissolved the solute sugar and the two substances did not separate on standing. A small amount of solute added to a solvent results in a weak (dilute) solution; a large

amount results in a strong (concentrated) solution. When the solute no longer dissolves in the solvent, the solution is saturated.

EXPERIMENT 2

Steps

1. Heat (do not boil) the saturated solution prepared in Experiment 1 and again add sugar until no more dissolves.
2. Pour off any undissolved sugar.
3. Let the solution cool, then examine it.

Observations

Hot water is almost always a better solvent than cold; thus you can dissolve more of the sugar after the water has been heated. This additional solute will reappear, however, when the solution cools.

■ PRECIPITATES

Purpose

Add one solution to another solution and what do you get? A third solution? Not necessarily. You could, instead, produce a solid material—white or bright—from the reaction of two clear liquids. This insoluble solid, which separates out of solution, is called a precipitate. Below are instructions which will enable you to produce three precipitates—in red, white, and blue.

Apparatus

¼ teaspoon dimethyl glyoxime
¼ teaspoon nickel sulfate
½ teaspoon potassium carbonate
¼ teaspoon calcium chloride
⅛ teaspoon ferrous sulfate
¼ teaspoon potassium ferricyanide
ethyl alcohol
water
6 pint bottles
glass stirring rod

EXPERIMENT 1

Steps

1. Fill one pint bottle ¼ full of water; fill another ¼ full of alcohol.
2. Add the dimethyl glyoxime to the alcohol and stir until it dissolves.
3. Add the nickel sulfate to the water and let it stand until it dissolves.
4. Add one solution to the other solution and stir. Let them stand.

EXPERIMENT 2

Steps

1. Fill two bottles ¼ full of water.
2. Add the potassium carbonate to one bottle, the calcium chloride to the other and stir until the solutes are dissolved.
3. Add one solution to the other solution and stir. Let them stand.

EXPERIMENT 3

Steps

1. Fill two bottles ¼ full of water.
2. Add the ferrous sulfate to one bottle and stir.
3. Add the potassium ferricyanide to the other bottle and let it stand until it dissolves.
4. Add one solution to the other solution and stir. Let them stand.

Observations

When the two solutions in Experiment 1 are brought together, the red precipitate nickel dimethyl glyoxime settles out on standing. When the two solutions in Experiment 2 are brought together, the white precipitate calcium carbonate settles out on standing. When the two solutions in Experiment 3 are brought together, the blue precipitate ferrous ferricyanide settles out on standing. Experiment 2 is a typical example of double replacement. When you add potassium carbonate, K_2CO_3, to calcium chloride, $CaCl_2$, the carbonate and chloride change places. The equation for this chemical reaction is $K_2CO_3 + CaCl_2 \rightarrow 2KCl + CaCO_3$.

SUSPENSIONS AND EMULSIONS

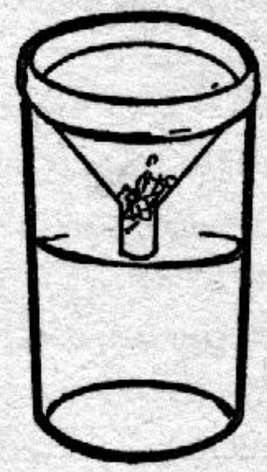
■ SUSPENSIONS

Purpose

What is the difference between a solution and a suspension? The following experiment will give you the answer.

Apparatus

2 glasses
1 jar
1 teaspoon sugar
1 teaspoon mud
water
funnel
filter paper (a disk cut from soft, fine paper such as newspaper)



Steps

1. Fill one glass with water, add the sugar and stir thoroughly.
2. Fill the other glass with water, add the mud and stir thoroughly.
3. Examine the two glasses. The sugar and water are so perfectly mixed that you no longer can distinguish between the two materials. The mud, however, is apparent throughout the water.
4. Fold the filter paper into a cone shape and wet it. Fit it into the funnel and set the funnel in the jar.

5. Pour the sugar-water combination through the filter. On examination you will find that no sugar has been filtered out.

6. Filter the mud-water combination. Flecks of mud will be caught by the paper.

Observations

A suspension is a fluid supporting fine particles which are distributed throughout it. These particles will settle to the bottom of the container. In a solution the solid added to a liquid is not visible (except as coloring) and will not settle. The materials that make up a solution don't separate when filtered; the materials that make up a suspension do.

■ EMULSIONS

Purpose

An emulsion is a combination of liquids that are not inclined to combine. It is the addition of a third ingredient—an emulsifying agent—that forces the uncooperative liquids to get together. Two experiments will demonstrate the characteristics of emulsions.

EXPERIMENT 1

Apparatus

water
water glass
salad oil
soap flakes
cake of soap
salt
teaspoon

Steps

1. Fill the glass halfway with water.

2. Add a teaspoon of oil and stir. Let the oil and water stand—they will quickly separate. Oil and water—as the old saying goes—do not mix.

3. Drop a teaspoonful of soap flakes into the glass and stir. You will find that the oil now spreads throughout the water and does not separate on standing.

4. Empty the glass and wash it out. Fill it again halfway with water.

5. Add salt until you have a saturated solution.

6. Pour some oil on your hands and try to wash them clean, using the salt water and the cake of soap.

Observations

The soap flakes in the first part of the experiment acted as an emulsifying agent, bridging the gap between water and oil and enabling them to mix. In the second part of this experiment, however, soap was unable to act as agent because it was impeded by the salt in the water. Since you can't have an emulsion without an emulsifying agent, the oil and water refused to mix and your hands remained greasy despite the washing.

EXPERIMENT 2

Apparatus

2 eggs
1 cup olive oil
¼ teaspoon salt
2 teaspoons vinegar
mixing bowl
egg beater

Steps

1. Let the eggs stand for a while at room temperature, then break, and separate yolks from whites. Discard the whites (or save them for your mother to use later).

2. Drop the yolks and salt into the mixing bowl and beat with the egg beater.

3. Mix in a teaspoon of vinegar and add ⅓ of the oil, drop by drop, beating steadily.

4. Slowly add the rest of the oil until the mixture thickens.

5. Now blend in the rest of the vinegar and refrigerate the whole concoction.

Observations

You have just prepared homemade mayonnaise, a most edible emulsion. The emulsifying agent in this combination is egg yolk, which joins oil and vinegar together.

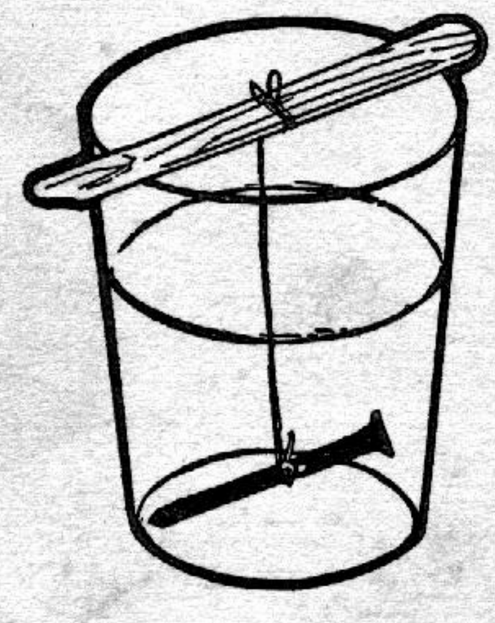
■ CRYSTALS ON A STRING

Purpose

Crystals are many things—sugar and salt, quartz and diamonds. In the following experiments we will work with kitchen-shelf materials to produce stringfuls of salt and sugar crystals.

Apparatus

sugar
salt
2 glasses
2 splints of wood
2 strings
water
pot
2 nails



EXPERIMENT 1

Steps

1. Pour a cup of cold water in the pot and add salt until no more dissolves.
2. Heat (do not boil) the solution and add a final teaspoon of salt.
3. While waiting for the solution to cool, weight one end of a piece of string with a nail and tie the other end to the center of the splint.

4. Pour the solution into the glass and place the splint across the top of it so that the string hangs down into the solution.
5. Let the glass stand undisturbed for a few days.

EXPERIMENT 2

Steps

1. Boil a cup of water in the pot, then remove from the heat.
2. Add sugar until no more dissolves.
3. Repeat steps 3 to 5 of Experiment 1.

Observations

As the water evaporates, the salt and the sugar come out of solution in crystal form. The string acts as a nucleus for the crystals, which grow up and around it. The crystals formed by the sugar are known as rock candy and can be eaten.

■ CRYSTALS ON A GLASS

Purpose

Grow crystals on the outside of a plain tumbler or vase, and you will have frosted glass.

Apparatus

Epsom salts (magnesium sulfate)
½ cup water
liquid glue
pot
small paint brush
tumbler or vase

Steps

1. Fill the pot with the water and boil. Turn off the heat.
2. Add Epsom salts until no more dissolves.
3. Add a few drops of liquid glue and stir.
4. Dip the brush into the pot and apply the liquid to the tumbler or vase.

Observations

In a short while the liquid evaporates and frosty crystals form on the glass.

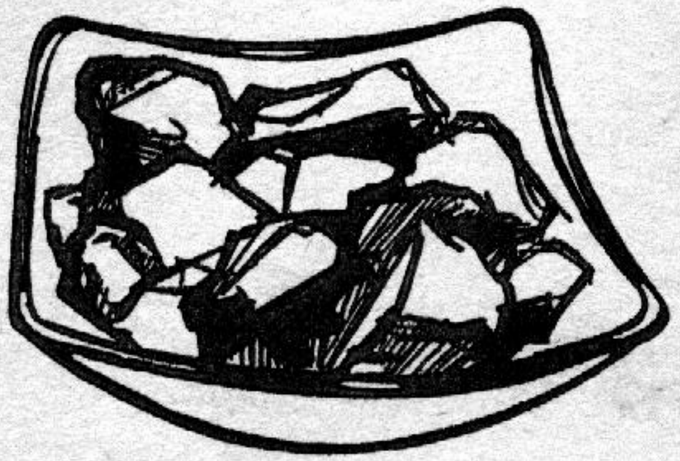
■ CRYSTALS IN A GARDEN

Purpose

When a solution of salt dissolved in water is left undisturbed, the water evaporates and the salt remains as beautiful crystals. In the following experiment we will apply this principle to growing a colorful crystal garden at home.

Apparatus

several small lumps of coal or coke
6 tablespoons salt
6 tablespoons water
1½ tablespoons ammonia water
12 drops of Mercurochrome
12 drops of bluing
large glass bowl or dish



Steps

1. Mix the salt, water, and ammonia water together.
2. Place the coal in the bowl and pour the liquid over it.
3. Drop the bluing on some pieces of the coal, the Mercurochrome on others.
4. Let the bowl stand undisturbed for several days.

Observations

Crystals will cling to the lumps of coal and cover them, growing in attractive patterns. The crystals will be the flowers of your garden, colored in part by the bluing and Mercurochrome, white where no coloring fell.

■ ACIDS AND ALKALIS

Purpose

Scientists have developed various tests for identifying unknown materials. Sometimes a test provides very precise identification; sometimes it merely indicates the general category into which Material X falls. Litmus paper is a most useful chemical private eye, for it indicates the presence of acids or alkalis (also called bases) and indicates, too, if the tested material is neutral (neither acid nor alkali). Below are some chemical tests using litmus paper.

Apparatus

6 strips of red litmus paper
6 strips of blue litmus paper
lemon juice
vinegar
ammonia water
milk of magnesia
milk
water
6 cups (or equivalent containers)
tablespoon

EXPERIMENT 1

Steps

1. Put 2 tablespoons of lemon juice in one cup, 2 tablespoons of vinegar in another. (Always wash the tablespoon before measuring out a new material.)
2. Take a small taste of each. Both will have the sour taste characteristic of acids.
3. Dip one piece of red litmus into the vinegar, another into the lemon juice. Do the same with two pieces of blue litmus.

Observations

Acids turn blue litmus paper red. The red litmus paper will remain red.

Experiment 2

Steps

1. Put 2 tablespoons of ammonia water in one cup, 2 tablespoons of milk of magnesia in another.

2. Do not taste or handle. Alkalis are bitter tasting, and ammonia water is poisonous.

3. Dip one piece of red litmus into the ammonia water, another into the milk of magnesia. Do the same with two pieces of blue litmus.

Observations

Alkalis (bases) turn red litmus paper blue. The blue litmus paper will not change color.

Experiment 3

Steps

1. Put 2 tablespoons of water in one cup, 2 tablespoons of milk in another. (Be sure that the milk is fresh.)

2. We will assume you have tasted both of these. If you recall, they are neither bitter nor sour.

3. Dip one piece of red litmus into the water, another into the milk. Do the same with two pieces of blue litmus.

Observations

A material which contains neither an acid nor a base is neutral. Materials are neutralized when an acid and an alkali are combined so that neither remains after the chemical change is complete. Neutrals do not affect litmus paper —the blue is still blue and the red is still red.

■ FLAME TESTS

(With qualified adult supervision only!)

Purpose

A chemical is added to a plain blue flame, and suddenly it burns with a yellow, or green, or crimson, or violet glow. Elements display characteristic colors when heated, as the following flame tests will show.

Apparatus

Bunsen burner
table salt
baking soda
cupric chloride crystals, just a few
potassium carbonate solution (½ teaspoon potassium carbonate to 1 glass of water)
pliers or tongs
piece of blue glass
nichrome wire, a few inches long

Steps

1. Light the burner and adjust to a blue flame.

2. Drop a little salt into the flame. Add a pinch of baking soda. What is the color of the flame now?

3. Use the tongs to grasp a cupric chloride crystal and hold it in the flame. What is the color?

4. Dip an end of the nichrome wire into the potassium carbonate solution. Grasp the wire with the tongs and hold the wetted end in the flame. What is the color?

Observations

The element sodium, present in both the table salt and the baking soda, gives a bright yellow color. Copper, present in the cupric chloride crystal, colors the flame green. Potassium colors it violet—if you get yellow, observe the flame through the blue glass to block out the impurities. Those who want to pursue flame tests further can try for a brilliant red strontium flame, an orange-red flame from calcium and a yellow-green flame from barium.

GASES

■ OXYGEN

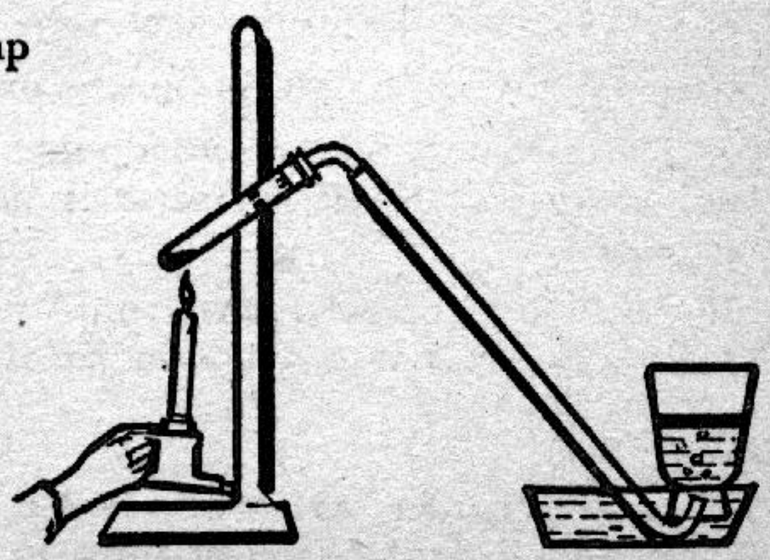
(With qualified adult supervision only!)

Purpose

Oxygen, as everyone knows, is vitally necessary to life. On earth we breathe it from the air; in space, astronauts carry along a supply of this gas in order to survive where no oxygen exists. Oxygen does not burn, but it supports combustion. That is why space rockets as well as spacemen must be equipped with oxygen in order to function beyond the earth. Directions for generating oxygen and demonstrating its ability to support combustion are given below.

Apparatus

5 grams potassium chlorate
2 grams manganese dioxide
water
spatula
piece of clean paper
dry test tube
one-hole rubber stopper
short length glass tubing
longer length rubber tubing
baking pan or trough
2 small jars
2 glass plates
piece of charcoal
long splinter of wood
Bunsen burner
ring stand and clamp
tongs or pliers
towel



Steps

First collect two jars of oxygen.

1. With the spatula thoroughly mix the potassium chlorate and the manganese dioxide on the paper. Do not grind or crush.

2. Transfer the mixture to the test tube and attach the stopper.

3. Insert the glass tubing through the stopper hole, attach the rubber tubing to the glass. Whenever you insert glass tubing through a stopper, wet the tubing to avoid breaking, and protect your hand by wrapping a towel around it.

4. Clamp the test tube to the ring stand.

5. Fill the pan halfway with water. Invert a jar of water into the pan. Extend the rubber tubing from the test tube into the mouth of the jar. Lean the jar against a corner of the pan to steady it.

6. Heat the test tube *very gently, slowly, and evenly* by moving the burner back and forth under it. As the oxygen is liberated from the potassium chlorate, it will displace the water from the jar. Let the oxygen bubble through the water at an even rate. If the bubbles are too rapid, apply less heat; if too slow, apply more heat.

7. When the jar is filled with oxygen (when all the water in the jar has been displaced), take the rubber tubing out of the pan immediately. (Otherwise the water in the pan will be sucked back into the hot test tube.) Slip a wet glass plate under the mouth of the jar and set it right side up on a table. Keep the covering on the jar till ready for use.

8. Fill the other jar in the same way.

Now try these experiments with the oxygen:

9. Ignite the splinter of wood, then blow it out. When only a spark remains, immerse it in one of the jars of oxygen.

10. Heat a piece of charcoal until it glows, then use the tongs to insert it into the other jar of oxygen.

Observations

The wood splinter burns anew in the bottle of oxygen, and the glowing charcoal flares brightly. In both cases the experi-

ment shows that oxygen supports combustion. The equation for obtaining oxygen is $2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2$. The manganese dioxide, whose formula is placed over the arrow, merely acts as a catalyst in this reaction. It forces the potassium chlorate, $KClO_3$, to release its oxygen faster, while remaining itself unchanged.

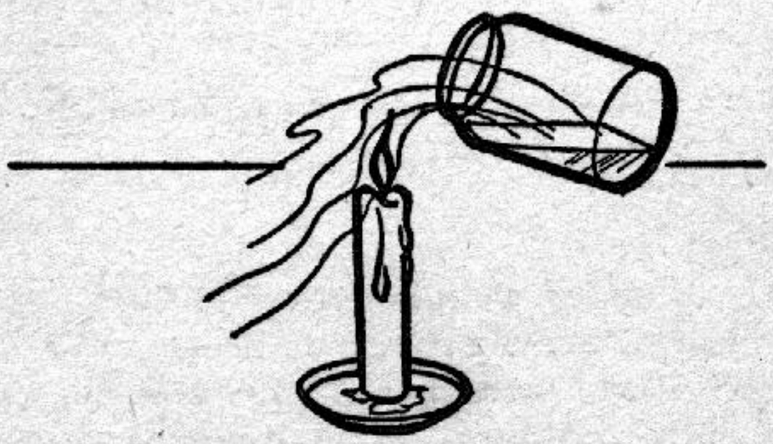
■ CARBON DIOXIDE

Purpose

Carbon dioxide, CO_2, turns up in a variety of places. It is used in fire extinguishers to battle flames, and in flavored water to produce *carbon*ated soda. In its solid form it is dry ice—so called because it goes from a solid to a gas state without going through the liquid state at all. Some of the properties of CO_2 are demonstrated in the experiments below, where you will also learn how to generate this gas from two simple around-the-house materials.

Apparatus

4 teaspoons baking soda
8 teaspoons vinegar
quart jar
pliers or tongs
wood splint
candle
small plate
6 tablespoons limewater
2 small jars



Experiment 1

Steps

1. Place ½ the baking soda in the quart jar and pour ½ the vinegar over it. A great fizzing and foaming will immediately occur as the acid in the vinegar reacts with the soda to form CO_2. Your quart jar now contains carbon dioxide gas.

2. Use the pliers or tongs to lower a lighted splint into the mouth of the jar. The flame will go out.

3. Wash out the quart jar and use the rest of the soda and vinegar to prepare more CO_2.

4. Light the candle and let some of the heated wax drip on the plate. Anchor the candle to the plate by pressing the bottom of it against the hot wax. Now that the candle is safely fastened, tip the quart jar over the candle flame and let the gas (not the liquid) flow over it. (Save some gas for the next experiment.) The flame will go out.

Observations

Fire will not burn in carbon dioxide because this gas neither burns nor supports combustion. It is possible to pour carbon dioxide out of the jar—just as you would pour a liquid—because this gas is heavier than air.

Experiment 2

Steps

1. Divide the limewater equally between the two small jars. Cap and shake. The limewater will remain clear, or cloud very slightly.

2. Pour the remaining CO_2 from your quart jar into one of the jars. Cap and shake. The limewater will become cloudy.

3. Breathe into the other jar. Cap and shake. The limewater will become cloudy.

Observations

When CO_2 is added to limewater, $Ca(OH)_2$, the resulting reaction forms calcium carbonate, $CaCO_3$, and water. Since no other gas affects limewater in this way, the change from clear to cloudy indicates the presence of carbon dioxide. The clouding that may occur in step 1 is due to the carbon

Steps

1. Push the stopper into the opening of the bell jar. Be sure it fits tightly.

2. Push the Y-tube into the stopper's hole, so that the two prongs of the tube hang into the jar.

3. Place a small balloon on the end of each prong, and hold each in position with a rubber band.

4. Cut a piece of rubber from the large balloon. It should be big enough to fit over the opening of the bell jar. Use the two remaining rubber bands to attach the rubber sheet to the opening.

5. Grasp the center of the rubber sheet and pull down on it. What happens to the balloons?

6. Grasp the center of the rubber sheet and push up on it. What happens to the balloons?

Observations

The two balloons represent the lungs; the rubber sheet represents the diaphragm; the tube represents the windpipe; the bell jar represents the rib cage. When we inhale, the diaphragm moves downward. The air pressure inside the rib cage is lowered, and the greater outside pressure pushes air through the windpipe into the lungs. Thus the lungs—the balloons—inflate. When we exhale, the pressure is greater inside, and air is forced out of the lungs and the windpipe. Thus the lungs—the balloons—deflate. (Note: In actual breathing, the rib cage—the bell jar—also participates by expanding when we inhale.)

■ THE CIRCULATORY SYSTEM

Purpose

Blood contains oxygen and dissolved food, which must be carried to all the cells of the body. It also contains dissolved wastes, which must be carried to organs that dispose of them. The circulatory system—the heart and a network of blood vessels—takes care of the movement of the blood. In the following experiments you will explore the circulatory system by examining blood cells, heartbeat, and pulse.

Apparatus

needle
matches

97% ethyl alcohol, or rubbing alcohol
cotton ball
2 slides
microscope
rubber tubing, 2 feet long
metal funnel
roll of adhesive tape
clock with second hand

EXPERIMENT 1

Steps

1. Sterilize the needle with the flame of a match. Pour some alcohol onto the cotton ball and clean the tip of your left forefinger by rubbing it with the cotton.

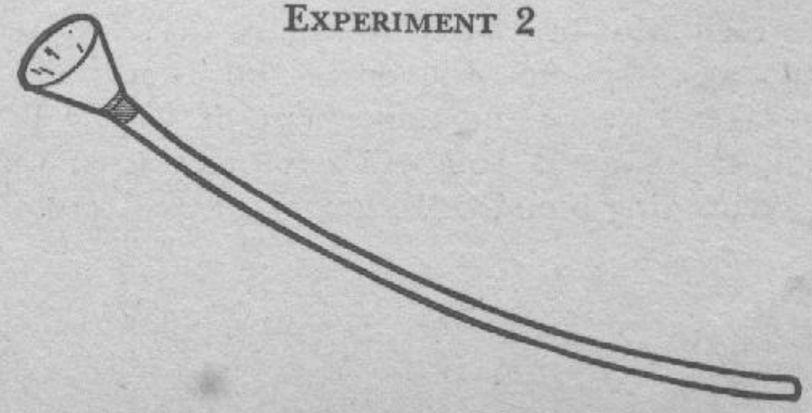
2. Squeeze your forefinger between thumb and second finger. Quickly jab the needle into your finger, just deep enough to cause bleeding. (Have a qualified adult supervisor standing by during this part of the experiment, to make sure that the conditions are sufficiently antiseptic. Do not do this experiment without asking permission from a parent.)

3. Squeeze the stuck finger and let a large drop of blood fall onto the end of a slide. Use a second slide to smear the blood thinly from end to end of the first slide, then observe the smear under the microscope. As soon as you have prepared the slide, and before you look at it, clean your finger again with the alcohol.

Observations

You will see red and possibly white blood cells under the microscope. The red cells will appear pink, and will be smaller and far more numerous than the whites. The red blood cells carry oxygen; the whites fight harmful bacteria. Lymph, the watery part of the blood, carries foods and wastes.

EXPERIMENT 2



Steps

1. Attach one end of the rubber tubing to the tube of the funnel.

2. If necessary, wrap adhesive tape around the juncture of tubing and funnel to make a tight attachment.

3. Place the funnel on a friend's chest, over the heart.

4. While the friend holds the funnel, you hold the open end of the tube to your ear with one hand. Cover your other ear with your other hand, and listen to the sound in the tube.

Observations

You will hear the beating of your friend's heart. The funnel amplifies the sound, and your covered ear is sheltered from other sounds that might interfere with the reception. The heart is divided into four chambers—two upper (auricles) and two lower (ventricles). The left auricle receives blood from the lungs, the right auricle receives blood from the rest of the body. The right ventricle pumps blood to the lungs, the left ventricle pumps blood to the rest of the body. The blood circulates from right auricle to right ventricle, into the lungs, then into the left auricle and left ventricle. Heartbeats are contractions of the left ventricle muscles.

Experiment 3

Steps

1. Place two fingers on the pulse on the inner side of your wrist and count the number of beats you feel in 60 seconds.

2. Touch your toes, run quickly up and down stairs, or do some other exercise for a minute or two. Now take your pulse again.

Observations

Veins carry blood to the heart; arteries carry blood away from the heart. When the blood is pushed into the arteries, the arteries stretch. Pulse rate is the number of these stretches occurring in 60 seconds. In step 1 you took your pulse under normal conditions. Step 2 shows that strenuous activity increases pulse rate.

■ THE FIVE SENSES

Experiment 1

Purpose

The following experiment will demonstrate that sensitivity to touch varies, depending on the part of the body that is contacted.

Apparatus

2 identical nails
small piece of cardboard

Steps

1. Push the nails into the cardboard, about ½ inch apart.

2. Ask a friend to close his eyes. Touch the back of his neck with the points of the nails. What does he feel?

3. Ask your friend to close his eyes and hold out his hand. Gently touch the tip of his finger with the points of the nails. What does he feel?

Observations

Your friend will feel the point of one nail in step 2, but will feel two nails in step 3. The finger tip has more touch receptors than the back of the neck does, and so is more sensitive to touch.

Experiment 2

Purpose

This experiment will test variations in hearing ability.

Apparatus

clock
yardstick

Steps

1. In a perfectly quiet room, hold the clock next to a friend's ear, then slowly move away in a straight line.

2. Ask your friend to tell you when he can no longer hear the ticking of the clock. Measure the distance from that point to where he is standing.

3. Repeat steps 1 and 2 with his other ear, then ask him to test your hearing in the same way.

Observations

It is possible that you will find that you and your friend have different hearing abilities, and that there are even differences between the hearing abilities of the left and right ears.

EXPERIMENT 3

Purpose

This experiment will show the relationship between the sense of smell and the sense of taste. It will also show that there are only four tastes which the tongue can recognize without the assistance of the nose.

Apparatus

peppermint chewing gum
sugar
salt
lemon
aspirin
4 glasses
water

Steps

1. Ask a friend to close his eyes and hold his nose. Put the gum in his mouth and tell him to chew it. Can he taste the peppermint flavor? Tell him to stop holding his nose and continue chewing. Can he taste the peppermint now?

2. Fill the four glasses with water. Add a teaspoon of sugar to one, a teaspoon of salt to another, squeeze half a lemon into the third, and dissolve the aspirin into the fourth.

3. Ask your friend to close his eyes and hold his nose. Have him take a sip, in turn, from each glass. How many tastes can he distinguish?

Observations

Your friend will not recognize the peppermint flavor as long as he holds his nose. The taste of the peppermint is due

to its aroma. However, the taste buds of the tongue can recognize the four tastes of the liquids prepared in step 2—sweet, salty, sour, and bitter.

EXPERIMENT 4

Purpose

For a split second after you stop viewing an object, its image remains on your retina. The following experiment will demonstrate the phenomenon of the afterimage.

Apparatus

black paper
white paper
scissors
paste

Steps

1. Cut out a circle from the black paper.

2. Cut two smaller circles from the white paper and paste them on the black circle.

3. Hold the black circle under a bright light and stare at it for a minute. Then lift your gaze to a blank wall that is only dimly lit. What do you see?

Observations

The circular design will appear on the wall with the big circle white and small circles black.

EXPERIMENT 5

Purpose

The human eye can distinguish size, depth, and distance, as well as color and form. But seeing is not always believing, for the eye can be tricked. The following experiment will demonstrate optical illusions.

Apparatus

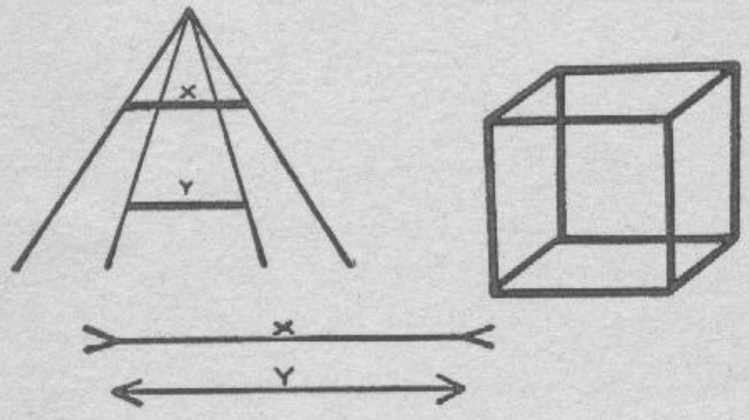
pencil and paper
ruler

Steps

1. Draw a four-sided figure with these dimensions: top, 2 inches; bottom, 3 inches; left and right, 1¼ inches. Top and bottom should be parallel. Below this figure draw another figure with these dimensions: top, 2 inches; bottom, 1 inch; left and right, 1¼ inches. Top and bottom should be parallel. Compare the appearance of the top lines.

2. Draw a 4-inch square. In the center draw a 1-inch square. Draw a line from the upper left corner of the small square to the upper left corner of the big square. Draw a line from the lower left corner of the small square to the lower left corner of the big square. Draw a line from the upper right corner of the small square to the upper right corner of the big square. Draw a line from the lower right corner of the small square to the lower right corner of the big square. Look at the figure. Can you see two views of it?

3. Look at the three figures in the illustration. What is the optical illusion of each figure?



Observations

The top lines of the figures drawn in step 1 are identical, but the line in the first appears longer than the line in the second. The inner square of the figure drawn in step 2 appears to be forward sometimes, rearward other times. In the upper left figure shown in the illustration, line X appears longer than line Y, but they are actually identical. The same is true of the lower left figure. The figure on the right displays two views—sometimes appearing to be the top of a cube, sometimes the bottom.

PART 4
WEATHER

Weather is determined by many conditions—by the pressure of the air and the moisture that is in it, by the sun and by the winds. The endless interaction of these factors is responsible for everything from the blazing, humid days of summertime to winter's bitter snows and freezing temperatures.

By coming to understand the circumstances that produce blizzards and heat waves, scientists have permanently removed weather prediction from the realm of aching corns and groundhogs' shadows. Precise instruments observing and tabulating weather conditions all over the world enable meteorologists to recognize a pattern in today's weather and to anticipate what tomorrow will bring.

The experiments presented here will demonstrate some of the whys of weather and will show you how to construct simple weather instruments. If you wish, you can keep daily records of barometric pressure, relative humidity, amount of rainfall, etc., and try some predictions of your own.

You will find, as you make your observations, that there are no such things as an "inexplicable" drop in temperature or a storm "coming out of nowhere." For behind these—and all the kinds of weather that exist—are orderly and logical processes of nature, processes that have been repeated and repeated since the beginning of time.

■ AIR IS MATTER

Purpose

It is impossible to understand weather without understanding air. And the first thing to understand about air is that it is matter—it has weight and it occupies space. The following experiments will demonstrate these two fundamental characteristics of air.

EXPERIMENT 1

Apparatus

12-inch ruler
drill
knife
3 pieces of string
2 balloons, same size, uninflated

Steps

1. Drill a hole above the 6-inch mark on the ruler, close to the upper edge.

2. With the knife, notch the ruler above the 1-inch mark and above the 11-inch mark.

3. Tie one of the strings through the hole and suspend the ruler from a table edge or shelf.

4. Tie a balloon to each of the other two strings, tie the strings into loops of equal size, and loop one of them over each notch. The ruler should be in balance. (If it is not, adjust the balloons until they are balanced on the ruler.)

5. Remove one of the balloons and blow it up. Return it to its place on the string and put the string on the ruler again, exactly where it was before. Is the ruler still balanced?

Observations

The ruler no longer balances because the air-filled balloon is heavier than the empty balloon. This experiment shows that air has weight.

EXPERIMENT 2

Apparatus

pan
water
water glass
piece of paper

Steps

1. Fill the pan ⅔ full of water.

2. Crumple the paper and fit it securely into the bottom half of the glass.

3. Turn the glass upside down and push it into the pan of water. (Be sure the paper stays in the same position.) Hold it there for a couple of minutes, then remove the glass and look at the paper.

Observations

The paper remains dry. Water does not fill the entire glass because the seemingly empty space in the glass is already occupied—by air.

■ AIR EXERTS PRESSURE

Purpose

Air is continuously pressing down on earth, and its pressure is an important determinant of our weather. For a vivid demonstration that air does, indeed, exert pressure, do the following experiment.

Apparatus

gallon can with flat sides and stopper
water
stove
pot holder

Steps

1. Fill the can with about 1 inch of water.

2. Set the can on the stove without the stopper, and boil the water for several minutes.

3. With the pot holder remove the can from the stove and replace the stopper securely.

4. Cool the can—either wait until it cools by itself or stand it in the sink and run cold water on it.

5. Observe the can as it cools. Its sides will collapse, as if some giant force has battered them in.

Observations

The powerful force that crushed the can is air pressure. The steam inside the can condensed as it cooled, forming a partial vacuum. The air outside the can exerted much more pressure than the air within, and so the can collapsed.

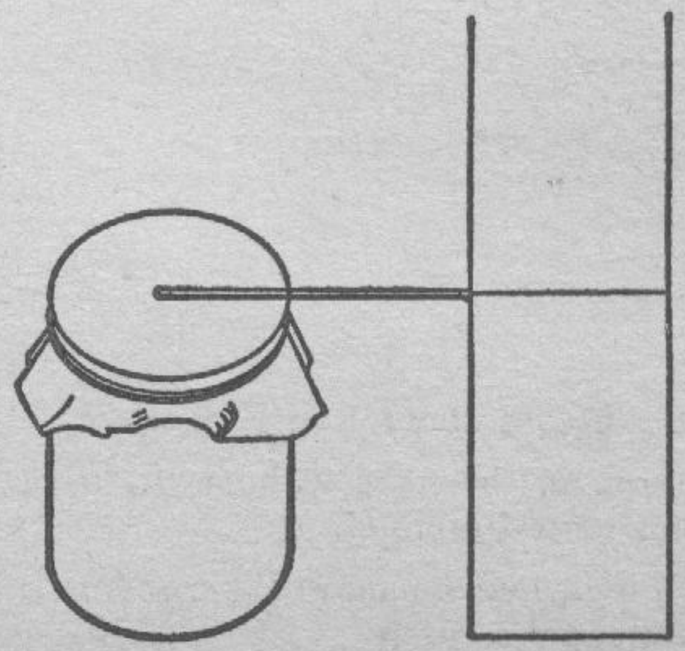
■ MEASURING AIR PRESSURE: THE BAROMETER

Purpose

A barometer is a scientific instrument that measures air pressure at a particular point. Below are instructions for making a simple version of this valuable weather-casting tool.

Apparatus

tin can, open at one end
balloon
rubber band
scissors
glue
straw from a broom
transparent tape
piece of paper, about 2 inches wide and twice the height of the can
pencil



Steps

1. Cut a square from the balloon and stretch it over the open end of the can to make a diaphragm. Hold it in place by wrapping the rubber band around the overlap.

2. Place the straw on the rubber diaphragm so that it extends horizontally from the diaphragm's center to an inch or two beyond the edge. Glue it securely.

3. Tape the piece of paper (longer dimension vertical) to a wall. It should be near the floor or above a shelf, away from radiators and direct sunlight. Place the can beside it. Arrange paper and can so that the free end of the straw touches the paper about halfway down from the top. Draw a line across the paper at this point.

4. Observe the straw over the course of several days. Changes in air pressure will cause it to move up or down on the paper.

Observations

When the air pressure on the outside of the diaphragm is greater than the pressure inside the can, the diaphragm—and the part of the straw attached to the center of the diaphragm—are depressed. When the straw is pushed down at the center it moves upward at the end, where it touches the paper. Rising barometric pressure generally means fair weather. When the straw moves down on the paper, however, barometric pressure is falling, and the weather will change or turn bad.

MOISTURE

■ EVAPORATION

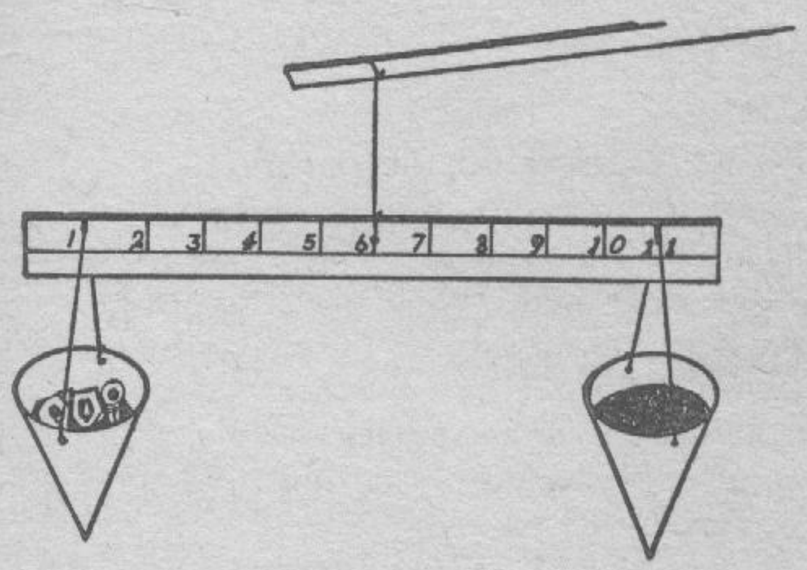
Purpose

Some moisture is always present in the air. Water enters the air by evaporation, by changing from a liquid to a gas (water vapor). Water is constantly evaporating from rivers and oceans, from the ground, from clothes drying on the line. Demonstrations of evaporation follow.

Apparatus

12-inch ruler
drill
knife
3 pieces of string
2 paper cups, same size
soil
assorted objects
stick
water
drinking glass
adhesive tape
2 pieces of cloth, same size
electric fan

EXPERIMENT 1



Steps

1. Drill a hole above the 6-inch mark on the ruler, close to the upper edge.

2. With the knife, notch the ruler above the 1-inch mark and above the 11-inch mark.

3. Tie one of the strings through the hole and use it to suspend the ruler from the stick. Then suspend the stick from a table edge or shelf so that the ruler swings freely.

4. Make two holes near the top of each paper cup, one hole directly opposite the other. Tie a string through each pair of holes in a loose loop.

5. Loop one cup over the ruler at the 1-inch mark, the other over the ruler at the 11-inch mark. The cups should be in balance.

6. Fill one cup halfway with well-moistened soil and fill the other cup with the assorted objects until the cups are again in balance.

7. After 24 hours check the cups. Are they still balanced on the ruler?

Experiments 2, 3, and 4

Steps

1. Fill the glass ¾ full of water and mark the water line with adhesive tape (or other practical substitute). Let the glass stand undisturbed for 24 hours. What happens to the water line?

2. Wet both pieces of cloth. Let one dry at normal room temperature; dry the other by turning the fan on it. Which piece dries first?

3. Pour water on your hand and wave it in the air. Does your hand feel cooler or warmer as it dries?

Observations

Water evaporates from the soil—the cups become unbalanced. Water evaporates from the glass—the water line falls. Evaporation is speeded by moving air—the fan-dried cloth dries faster. When water evaporates from a surface, heat is removed from that surface—your hand feels cooler.

■ RAIN

Purpose

Warm air can hold more moisture than cool air can. When warm air up in the sky is cooled, the water vapor it contains condenses into tiny droplets, forming a cloud. If cooling continues, the drops increase in size, become too heavy for the air to hold, and fall to earth as rain. The following experiments will demonstrate this process and will show how you can measure the amount of rain that falls.

Experiment 1

Apparatus

stove
kettle
metal baking pan
ice cubes
water

Steps

1. Fill the kettle part way with water and set it on the stove to boil.

2. Place the ice cubes in the metal pan.

3. Hold the pan above the kettle's spout, so that it is struck by the cloud of steam which comes out of the spout. What happens?

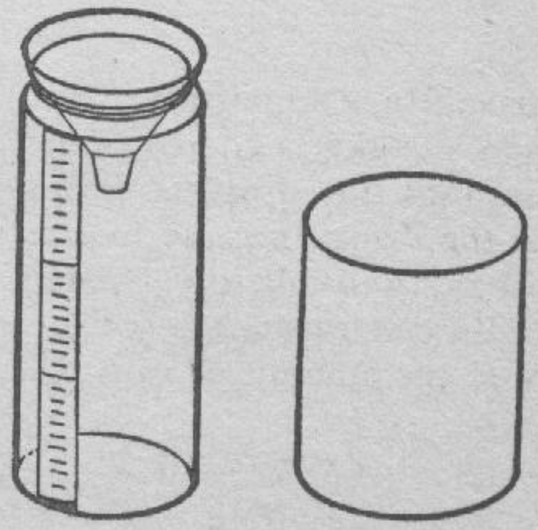
Observations

The hot moist air from the kettle is cooled when it leaves the spout. Water vapor condenses, forming a cloud. The cloud is then cooled by the icy pan, and the droplets of water within the cloud grow larger, until it begins to "rain."

Experiment 2

Apparatus

large fruit-juice can or other metal container with perfectly vertical sides and a flat bottom, top removed
ruler
water
narrow glass jar with vertical sides, flat bottom
strip of paper 1 inch wide, same height as glass jar
glue
pencil
funnel



Steps

(Note: The can, with its top removed, will serve as a rain collector. But before you collect any rain, you must devise a precise way of measuring it. Instructions follow.)

1. Fill the can with water to the height of 1 inch. Use your ruler to measure the height of the water accurately.

2. Pour this inch of water into the jar. Glue the strip of paper down the side of the jar and mark the water level on the strip with a heavy line. (You can spill out the water now.)

3. Measure off equal distances to the top of the bottle, also marking them with heavy lines on the paper strip. Then subdivide each section into ten equal parts. Remember, the large sections indicate inches and the subdivisions indicate tenths of inches *in terms of the can.*

4. To collect the rain, place the can outside in an open area where it will catch the rain from all directions. To prevent it from tipping in a strong wind, dig a hole several inches deep and set the can inside it. Empty the can each day.

5. Measure the amount of rainfall on a given day by pouring the rain water from the can through the funnel into the jar. Make your measurement as soon as the rain stops, to prevent loss of water through evaporation.

Observations

Your can, funnel, and jar will serve nicely as a simple rain gauge. In more elaborate gauges, however, the gathering and measuring devices are combined into one instrument.

■ FOG AND DEW

Purpose

Fog occurs when moist air is cooled at the surface of the earth by the ground or by the sea. Some of the water vapor condensing from the newly cooled air forms tiny drops which latch on to dust particles and float as a low-lying cloud. Dew occurs when air is cooled at night by the ground, and water vapor condenses on low-lying objects, such as leaves and grass and flowers. In the following experiments you will produce indoor versions of fog and dew.

Apparatus

milk bottle
cup of hot water
ice cubes
metal can

EXPERIMENT 1

Steps

1. Pour the cup of hot water into the bottle and set an ice cube in its mouth. Don't let the ice cube fall in.

2. Observe what happens on the inside of the bottle.

EXPERIMENT 2

Steps

1. Put several ice cubes inside the metal can, making sure that the outside is perfectly dry.

2. Observe what happens on the outside of the can.

Observations

In Experiment 1 the hot water makes the air inside the bottle warm and moist. The air rises, and is suddenly cooled by the ice. As the temperature falls, water condenses in light drops, making a swirling "fog" inside the bottle. In Experiment 2 the temperature of the outside air is lowered when it comes in contact with the surface of the colder ice-filled can. The water vapor in the air condenses, forming "dew" on the outside of the can.

■ FROST

Purpose

When below-freezing temperatures cool air close to the ground, moisture comes out of the air in a frozen state—as ice crystals—and frost appears on grass and windowpanes. Follow the instructions below and produce homemade frost.

Apparatus

ice cubes
3 tablespoons of salt
metal can

Steps

1. Fill the can with ice cubes.

2. Add the salt to the ice.

3. After a few minutes observe the outside of the can.

Observations

Frost forms on the outside of the can, because the temperature of the can is below freezing. The salt has lowered the melting point of the ice.

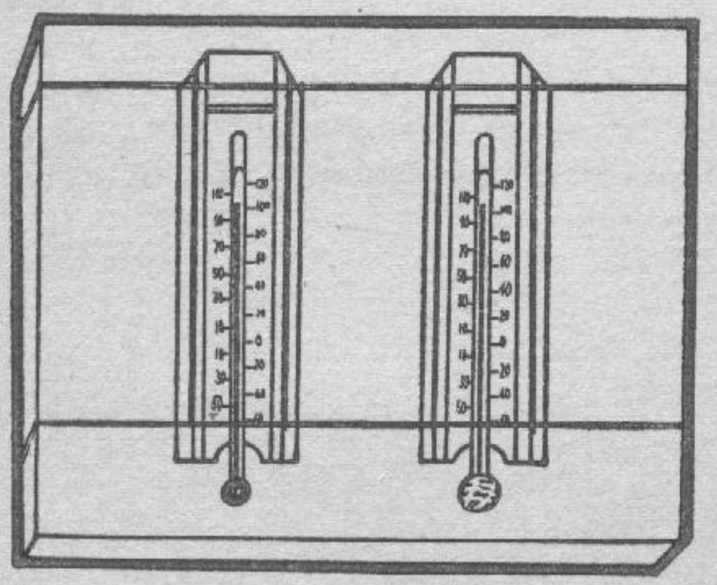
■ HUMIDITY

Purpose

Humidity is the amount of moisture (water vapor) dissolved in the air. Relative humidity (expressed as a per cent) is the amount of moisture the air is actually holding at a given temperature compared to the total amount of moisture it could hold at that same temperature. Relative humidity of 100% always means that the air is saturated—is holding all the moisture it can hold; relative humidity of 50% always means that the air contains half the amount of water it can hold, etc. Below are instructions for constructing a psychrometer—a device that measures relative humidity.

Apparatus

2 identical thermometers (Fahrenheit)
wooden board (A bread board is fine.)
2 rubber bands
wad of cotton
water



Steps

1. Moisten the wad of cotton thoroughly and pull it out until it is thin enough to be wrapped tightly around the entire bulb of one thermometer. There should be a free

circulation of air around the bulb. (If there is not, cut away the plastic or other material surrounding the bulb and let it hang freely.)

2. Place the thermometers side by side on the board. Allow a few inches between them. The bulbs should point toward the ground.

3. Hold the thermometers in place by wrapping the rubber bands over them and the board, one near the top, the other near the bottom. Stand the board outdoors where there is a free circulation of air, but avoid direct sunlight.

4. Fan the air around both bulbs for 3 or 4 minutes, until the temperature of the wet-bulb thermometer no longer drops. Then write down the temperature reading of each thermometer. Subtract the wet-bulb temperature from the dry-bulb temperature.

5. Turn to the Relative Humidity Table at the back of the book. By using the figures obtained in step 4, you can determine the relative humidity.

Observations

If there is a great difference between the amount of water vapor in the air and the amount it can hold, evaporation is rapid and much cooling occurs. Evaporation cools the wet-bulb thermometer, which registers a lower temperature than the dry. If there is a great difference between the readings of the two thermometers, the table shows a low relative humidity. If the air is holding almost all the water vapor it can hold, evaporation is slow and little cooling occurs. Thus the readings are almost the same and the table tells you the humidity is high.

WIND

■ WIND RATINGS

Purpose

Wind is moving air. It can be gentle or violent, depending on the speed with which it moves. You can rate winds from calm to hurricane by using a 12-point scale designed by an Admiral Beaufort. See the experiment below.

Apparatus

pencil and large piece of paper
ruler
observant eyes
common sense

SCALE NUMBER	WIND DESCRIPTION	WIND SPEED	WIND EFFECT
0	calm	under 1	
1	light air	1-3	
2	light breeze	4-7	

Steps

1. Divide the paper into four vertical columns. (Read the experiment through to determine how wide each column should be.)

2. Label across the top of each column as follows: scale number, wind description, wind speed, wind effect.

3. Number down the first column from 0 to 12.

4. Label down the second column as follows: calm, light air, light breeze, gentle breeze, moderate breeze, fresh wind, strong wind, high wind, gale, strong gale, whole gale, violent storm, hurricane.

5. Number down the third column as follows: under 1, 1–3, 4–7, 8–12, 13–18, 19–24, 25–31, 32–38, 39–46, 47–54, 55–63, 64–75, over 75.

6. Here are 13 wind descriptions. They are not in the proper order: (a) Trees are uprooted. (b) Drifting smoke shows wind direction. (c) Small trees sway. (d) Smoke rises vertically; flags are limp. (e) Leaves rustle; wind vanes turn. (f) It is hard to walk against the wind; whole trees sway. (g) Damage is widespread. (h) Flags blow straight out. (i) Destruction is widespread. (j) Branches break from trees; there is some slight damage to buildings. (k) It is extremely hard to walk against the wind; twigs break from trees. (l) Large branches move; outdoor telephone wires whistle. (m) Dust starts blowing. Can you list these descriptions correctly in the fourth column?

Observations

The list should appear in the following order: d, b, e, h, m, c, l, f, k, j, a, g, i. Your Beaufort Scale is now complete. Although it is not an exact scientific standard, it will be useful in giving you a rough estimate of wind speed.

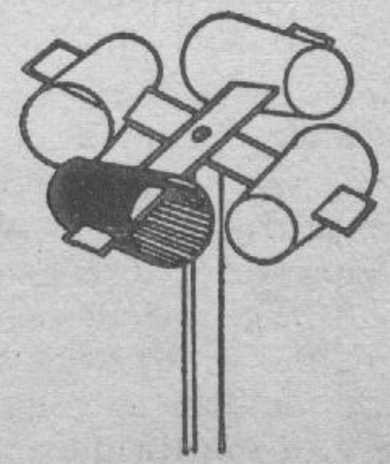
■ THE ANEMOMETER

Purpose

The anemometer is a more precise tool for measuring wind speed. It is usually composed of three or four cups attached to horizontal arms set on a vertical shaft. The wind blows into the cups, making the arms turn, and a meter automatically clocks the speed in miles per hour. To make and use a simple version of the anemometer, do the following experiment.

Apparatus

8 pieces of cardboard, each 4 inches by 12 inches (Cut them from the cardboard that comes back with shirts from the laundry.)
stapler
scissors
ruler
4 paper cups, 3 white (or any color), 1 red (or any other color)
transparent tape
2 washers
small screw and screwdriver
wooden shaft, 12 inches long
clock with second hand



Steps

1. Place four pieces of cardboard in one pile, four pieces in another, one on top of the other.

2. Make an X by placing one pile between the strips of the other pile so that two strips are above and two are below.

3. Staple the strips together securely.

4. Attach the four cups to the four arms of the X so that all cup openings face in a counterclockwise direction. To do this, cut vertical slits in the front and back of each cup—wide enough to accommodate the arms—and push the arms through the slits. The cups should be about ½ inch from the outer ends.

5. Make a hole in the center of the X and use the tape to cover the rough edges around the hole.

6. The X should be attached horizontally to the vertical shaft as follows: place a washer on the screw, push the screw through the hole of the X, place the second washer below the X, and then screw the ensemble into the top of the shaft. The X must turn freely, but should not flop around.

7. Mount the anemometer where the wind can hit it from all directions. Count the number of times it turns in 30 seconds and divide by 5. (Every time the red cup passes, a turn is complete.) The resulting figure is the present wind speed in miles per hour.

Observations

For a more accurate reading from your anemometer, calibrate it in the following way. On a calm day sit in a car and hold the anemometer by its shaft out the front window. Have someone drive the car at a steady 5 mph. Count the number of times the anemometer turns at this speed within 30 seconds. Repeat at 10, 15, 20, 25 miles per hour. Make a chart of your findings.

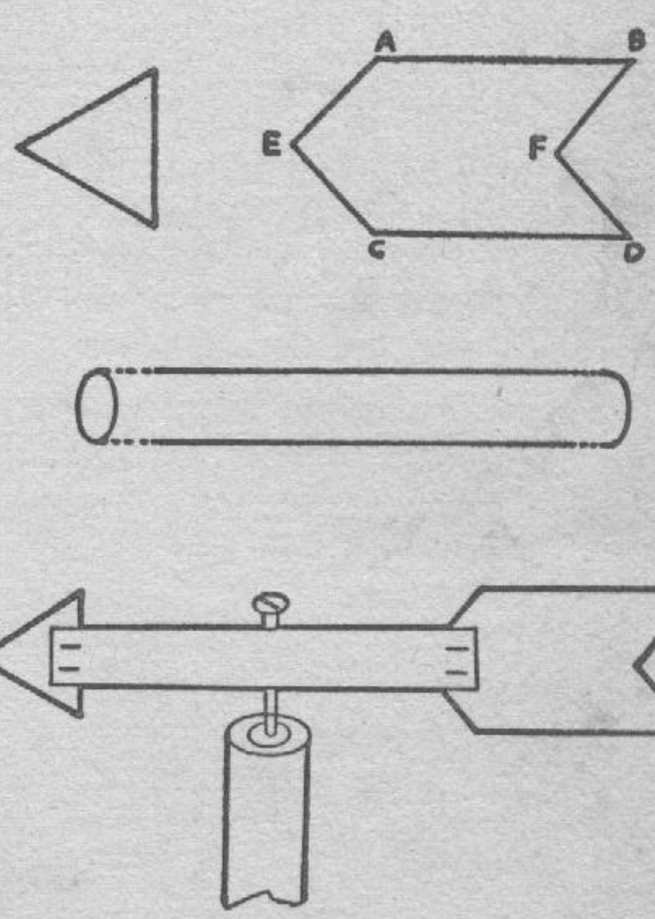
■ THE WIND VANE

Purpose

The wind vane (also called a weather vane) points in the direction from which the wind is blowing. (It is this direction that gives the wind its name.) To construct a simple wind vane, follow the instructions below.

Apparatus

3 pieces of cardboard, one 4 inches by 8 inches, two 6 inches square
ruler
pencil
scissors
stapler
long thin nail
washer
hammer
wooden shaft, 12 inches long
compass



Steps

1. Roll the 8-inch-long piece of cardboard into a cylinder and staple it in place. This will be the center section of your vane.

2. Cut a pointer and a tail from the cardboard squares, using the illustrations as your models. The pointer should be an equilateral triangle, 3 inches on each side. The tail should measure 4 inches from A to B and C to D, 2 inches from B to F and D to F, 2½ inches from A to E and C to E.

3. Make horizontal slits, about 1 inch long, at each end of the cylinder, top and bottom. (Make your cuts in the places indicated by dotted lines in the illustration.)

4. Put the pointer between the slits at one end, the tail between the slits at the other end, using the illustration as your model. Staple the pointer and tail in place.

5. Find the point along the cylinder at which the completed vane balances. Push the nail through the cylinder at this point and place the washer on the nail, beneath the cylinder.

6. Hammer the nail part way into the wooden shaft. Hold the shaft, and fan or blow the vane to be sure it moves freely around the nail.

7. Mount the vane where all the winds will strike it. Locate north with your compass so you can read your wind vane accurately.

Observations

Wind direction is often an indication of the weather. Keep a record of the winds and the weather they bring to your part of the country.

CLOUDS

■ THE NEPHOSCOPE

Purpose

Wind direction high in the sky is often different from wind direction close to earth. A good observer keeps records of both for a more complete picture of the weather. By watching the movements of clouds, you can determine in which direction the upper winds are blowing. To make your observations, build a useful cloud-gazing instrument called the nephoscope.

Apparatus

circular mirror, 4 to 6 inches in diameter
nail polish, or white paint
piece of cardboard, 8 to 10 inches square
compass
pencil
light, easy-to-move table

Steps

1. Put the mirror, reflecting side upward, in the center of the cardboard. Trace its outline with the pencil, to make certain you always return the mirror to the same place.

2. With the nail polish make a small dot in the center of the mirror.

3. Place the table outside, where the ground is perfectly level. Set the cardboard and mirror on top of the table.

4. Use the compass to locate north, then mark the compass points—N, NE, E, SE, S, SW, W, NW—all around the mirror on the cardboard.

5. To use your nephoscope, look into the mirror and watch for a cloud to cross the nail-polish dot. Follow this cloud until it passes from sight over the mirror's edge.

Observations

The point at which the cloud image drifts off the mirror (S, for example) is the direction *toward* which the wind is blowing. The point directly opposite (N) is the point *from* which the wind is blowing and for which the wind is named. In this example the upper wind is recorded as a north wind.

■ CLOUD TYPES

Purpose

Become acquainted with clouds by making models of the three basic types: cirrus, stratus and cumulus.

Apparatus

3 pieces of cardboard, 4 inches by 8 inches
box of cotton
glue
pen or pencil

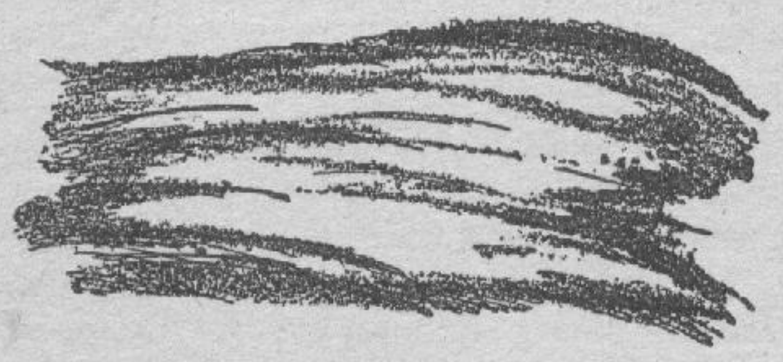
Steps

1. Pull out some of the cotton to form long hairlike strands with curly ends. Glue them on a piece of cardboard in wisps curving upward across the sheet. Label this model *cirrus*.

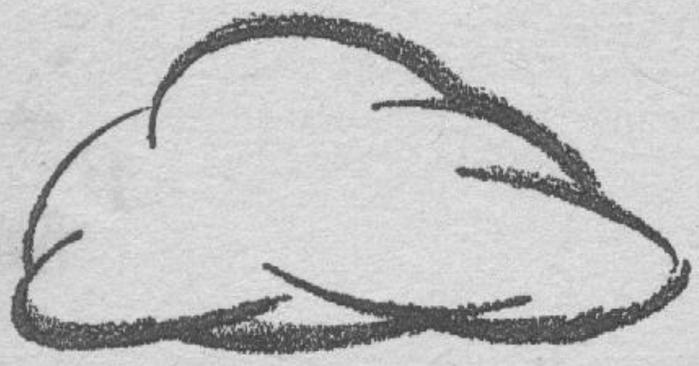
2. Stretch some of the cotton into a solid horizontal line about ½ inch from top to bottom, about 5 inches from



CIRRUS



STRATUS



CUMULUS

left to right. Repeat with three or four other pieces. Glue them on another piece of cardboard, one beneath the other, to give an appearance of a flat uniform layer. Label this model *stratus.*

3. Fluff up some of the cotton to make a fleecy heap with a rounded top and a flat base. Glue this model on the remaining piece of cardboard and label it *cumulus.*

Observations

Clouds are good signs of approaching weather. Cirrus clouds, very high in the sky, often foretell a coming storm. Stratus clouds may bring drizzle and gray skies. Cumulus clouds are fair-weather clouds, but can build up to thunderheads—

always a sign of rain. Scientists have subdivided these three cloud types into ten classifications: cirrus, cirrocumulus, cirrostratus, altocumulus, altostratus, nimbostratus, stratocumulus, stratus, cumulus, and cumulonimbus. (For more information on clouds, write to the U.S. Weather Bureau, Washington 25, D.C., and ask for its chart of Cloud Forms.)

TEMPERATURE

■ THE SLANT OF THE SUN'S RAYS

Purpose

Everyone knows that it is cold in the winter, hot in the summer, warm in the spring, and cool in the fall—all exceptions granted. One important explanation for changing seasons is that the sun's rays strike the earth at different angles at different times of the year. The less the sun's rays slant, the higher the temperature; the more they slant, the lower the temperature. The following experiments will show you why.

Experiment 1

Apparatus

flashlight
2 pieces of black paper
white chalk

Steps

1. Place a piece of the paper flat on a table, hold the flashlight slightly above it, and aim the beam directly down on it. Ask a friend to use the chalk to outline the spot of light on the black paper.

2. Repeat step 1 with the other piece of paper, this time holding the flashlight at an angle.

3. Compare the outlined spots of light in steps 1 and 2.

Observations

The spot of light is smaller in step 1, when the beam is direct, than in step 2, when the beam is at an angle. If the flashlight is the sun and the paper is the land, the land is

getting a greater concentration of rays from the direct hit. Thus the temperature of the land is higher. The same number of rays, when spread out over a wider area, as in step 2, provide each segment of that area with less heat. Thus the temperature of the land is lower.

Experiment 2

Apparatus

drinking glass
water
ruler

Steps

1. Fill the glass with 4½ inches of water. (Measure the water level by standing the ruler next to the glass, on the outside.)

2. Now stand the ruler inside the glass, holding it perfectly straight. Remove the ruler and note that it is wet up to the 4½-inch mark.

3. Dry the ruler and put it back in the glass, this time at an angle. Is the water mark higher, lower, or the same as in step 2?

Observations

When the ruler is placed in the glass at an angle, it travels through more water than when it goes in straight. Thus the water mark is higher in step 3. In a similar way sun rays traveling to earth pass through more of the atmosphere when slanted than when straight. Since the atmosphere absorbs some of the radiant energy before it reaches the earth, more radiant energy is lost by the slanted rays, less heat reaches the ground, and the temperature is lower.

■ HEATING LAND AND SEA

Experiment 1

Purpose

In December the sun shines for about 9 hours a day; in July it shines for about 15 hours. The longer the sun shines, the warmer the weather, as the following experiment will show.

Apparatus

2 identical pans
2 identical thermometers
soil, enough to fill one pan
light, easy-to-move table

Steps

1. Bring the table outside on a sunny day and set the pans on top of it.

2. Divide the soil equally between the pans, and place a thermometer in each. (Don't allow the thermometers to touch bottom.)

3. After 15 minutes read the thermometers and record the temperatures. They should be identical.

4. Remove one pan and let the other remain for 15 minutes more. Now read the thermometer again and compare it with the readings in step 3.

Observations

The soil that remains in the sun for a total of 30 minutes has a higher temperature than the soil exposed for only 15 minutes. The temperature increases because the soil has a longer time to absorb the heat of the sun.

Experiment 2

Purpose

This experiment will demonstrate that the sun heats soil faster than it heats water. Soil, however, cools off more rapidly than water does.

Apparatus

2 identical pans
soil, enough to fill a pan
water, enough to fill a pan
light, easy-to-move table
refrigerator

Steps

1. Bring the table outside on a sunny day and set the pans on top of it.

2. Fill one pan with the soil, the other with the water, and let them sit in the sun for ½ hour.

3. Touch the top of the soil and the top of the water with your hand. You should easily be able to tell which is warmer.

4. Place the pans in the refrigerator for ½ hour, then repeat step 3.

Observations

The soil is warmer than the water in step 3, cooler than the water in step 4. Because the sun heats only the surface of the soil, the soil collects and loses heat more quickly than the water, which is warmed throughout.

■ FAHRENHEIT AND CENTIGRADE

Purpose

There are two widely used thermometer scales for measuring temperature—Fahrenheit and centigrade. Below, you will be introduced to these scales and will learn how to convert one to the other.

Apparatus

pencil and paper

EXPERIMENT 1

Steps

1. On the Fahrenheit scale, the boiling point of water is 212° and the freezing point is 32°. On the centigrade scale the boiling point is 100° and the freezing point is 0°. How many degrees does the Fahrenheit scale have? How many degrees does the centigrade scale have?

2. Using the figures obtained in step 1, determine the relationship between a centigrade degree and a Fahrenheit degree.

Observations

There are 180 degrees on the F. scale (212 minus 32). There are 100 degrees on the C. scale (100 minus 0). A Fahrenheit degree is 5/9 (that is, $^{100}/_{180}$) of a centigrade degree. A centigrade degree is 9/5 (that is, $^{180}/_{100}$) of a Fahrenheit degree.

EXPERIMENT 2

Steps

1. When a thermometer registers 77° F., it is 25° C. Can you convert 122° F. to centigrade?

2. When a thermometer registers 5° C., it is 41° F. Can you convert 40° C. to Fahrenheit?

Observations

We converted 77° F. to 25° C. as follows:
$77 - 32 = 45$; $45 \times 5/9 = 25$.
We converted 5° C. to 41° F. as follows:
$5 \times 9/5 = 9$; $9 + 32 = 41$.
If you used this method to make the conversions in steps 1 and 2, your answers will be 122° F. = 50° C. and 40°C. = 104° F.

The story of numbers probably began with the first man who recognized that he had more fingers than eyes, and more teeth than fingers. Between then and now, people have learned to add four sticks to five sticks, subtract one goat from three goats, multiply width by length, and divide Gaul into three parts. They have also learned—quite recently—to turn over many lengthy and complex number problems to electronic computers, which can find the answers faster than mathematicians can ask the questions.

The experiments in this section include a variety of number problems: some not-so-easy arithmetic, some not-so-difficult algebra and geometry, some ways to measure length and weight. The apparatus required for these experiments is often very simple: If you have one clear head, you are ready to begin.

■ THINKING WITH NUMBERS

Purpose

Here are some warming-up exercises to get you into the swing of thinking with numbers. See how many of these old problems you can solve.

Apparatus

pencil and paper
clear head

Problems

1. If a vase and a flower cost $1.10, and the vase costs $1 more than the flower, what is the price of each?

2. Two banks offered Milton a job. Both said they would start him at a salary of $350 a month. The National Bank said it would give him a $5 raise every six months. The Federal Bank said it would give him a $10 raise every year. In which job would he make more money? Or are the offers the same?

3. A snail is trying to climb out of a 10-foot well. He crawls up 3 feet each day and slides back 2 feet each night. How long will it take him to climb out of the well?

4. There are 6 pairs of gray socks and 6 pairs of green socks in the dresser drawer. If you went to the drawer blindfolded, how many socks would you have to take out to be sure of having a pair?

5. If 6 boys eat 6 sandwiches in 6 minutes, how many boys are needed to eat 100 sandwiches in 100 minutes?

Observations

If you couldn't solve the above problems, here are the answers. Can you figure out how we got them? 1. The vase costs $1.05; the flower costs $ .05. 2. The National Bank is offering more money. 3. Eight days. 4. Three socks. 5. Six boys.

■ ADDITION-SUBTRACTION SLIDE RULE

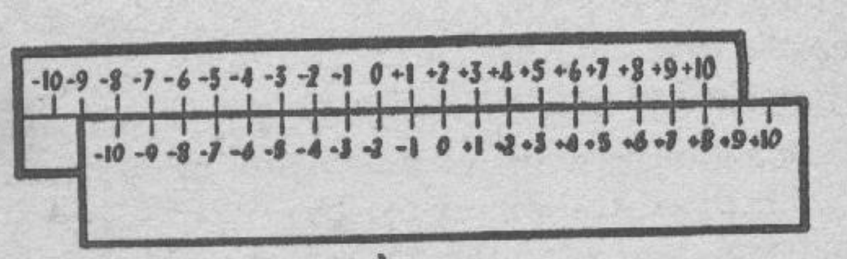
Purpose

Various gadgets have been invented to make computation less difficult and more accurate. This experiment will show

you how to construct and use a simple computing device—an addition-subtraction slide rule.

Apparatus

piece of white paper, 11 inches by 1⅝ inches
piece of thick cardboard, 11 inches by 3⅝ inches
scissors, razor, or knife
glue
ruler
pencil



Steps

First prepare the slide rule:

1. Hold the white paper with its 11-inch sides horizontal. Draw a line (let's call it *x*) from left to right, ⅝ inches down from the upper edge.

2. Draw 21 parallel lines, ½ inch long and ½ inch apart, bisected perpendicularly by line *x*. The eleventh line should be in the exact center of *x*.

3. At the top of each parallel line number as follows: −10, −9, −8, −7, −6, −5, −4, −3, −2, −1, 0, +1, +2, +3, +4, +5, +6, +7, +8, +9, +10. Do the same at the bottom of the lines.

4. Cut along line *x*. You now have two scales with identical markings.

5. From the cardboard cut three strips each 1 by 11 inches, and a fourth strip ⅝ by 11 inches. Be sure your measurements are exact, and don't bend the cardboard.

6. Make a sandwich of three of the cardboard strips, placing the narrow strip between two wide ones. Line up one side of the three strips and glue securely together. Don't paste the top of the two wide strips to each other—they must stand apart to provide a slot through which the fourth strip can slide.

7. You now have the base of your addition-subtraction slide rule. To complete it, smoothly glue the wide scale along one length of it.

8. To the upper part of the fourth strip paste the narrow scale. Be sure that the numbers of the sliding scale and the base are aligned perfectly when the sliding scale is in the slot. Also make sure that the strip slides easily through the slot.

Now you are ready to add and subtract with your rule.

9. The zero point on each scale is called the index. To add +6 and +3, put the index of the sliding scale over the +6 on the base. Locate +3 on the sliding scale, and you will find your answer directly under it.

10. Try adding a negative number (−5) to a positive number (+2). Place the top index over +2, locate −5 on the sliding scale, and read the answer directly under it, on the base.

11. To subtract +4 from +9, line up the +4 on your sliding scale with the +9 on the base. You'll find your answer beneath the index of the sliding scale.

12. Your addition-subtraction slide rule will also subtract two negative numbers. To subtract −1 from −8, place the −1 of the sliding scale above the −8 of the base, and look under the top index for your answer.

Observations

The numbers on your addition-subtraction slide rule represent distances, with the index as your constant starting point. It is a helpful fact to keep in mind when using this computing device. You might also want to be reminded of the rule for subtraction: change the sign of the number being subtracted—and add.

■ HOW DO YOU WRITE . . . ?

Purpose

How do you write the number 3, using four 5's? It's easy, if you do it like this— $\frac{5+5+5}{5}$. With only the addition, subtraction, multiplication, and division signs, and the numbers given below, see if you can do the following problems.

Apparatus

pencil and paper
clear head

Problems

1. How do you write 0, using two 7's?
2. How do you write 30, using three 6's?
3. How do you write 8, using four 4's?
4. How do you write 1, using four 3's?
5. How do you write 9, using three 8's?
6. How do you write 720, using four 9's?
7. How do you write ½, using four 2's?
8. How do you write ⅓, using four 1's?
9. How do you write 4, using four 5's?
10. How do you write 3, using four 10's?

Observations

Here are our answers: (1) $7 - 7$; (2) $(6 \times 6) - 6$; (3) $4 + \frac{4 \times 4}{4}$; (4) $3 - \frac{3 + 3}{3}$; (5) $\frac{8}{8} + 8$; (6) $(9 \times 9 \times 9) - 9$; (7) $\frac{2 - \frac{2}{2}}{2}$; (8) $\frac{1}{1 + 1 + 1}$; (9) $\frac{(5 \times 5) - 5}{5}$; (10) $\frac{10 + 10 + 10}{10}$.

■ MAGIC SQUARES

Purpose

In a magic square, the sum of each horizontal column, each vertical column and the two diagonals is the same. The square is made up of the numbers 1, 2, 3 . . . , one number used for each division on the square, no number used more than once. See if you can discover the pattern in magic squares and make a square of your own.

Apparatus

pencil and paper
clear head

EXPERIMENT 1

Steps

1. Draw a square divided into three rows of three squares each.

2. In the first row fill in the left square with the number 4, the middle square with number 9.
3. In the second row fill in the middle square with number 5, the right square with number 7.
4. In the third row fill in the left square with number 8.
5. Now fill in the blanks to make a magic square, using up the rest of the numbers between 1 and 9.

Observations

Each column and diagonal will add up to 15.

EXPERIMENT 2

	5		4
11			
			10
		8	

Steps

1. Draw a square divided into four rows of four squares each.
2. Fill in number 5 in the second from left square, row 1. In the same row fill in number 4 in the right square.
3. Fill in number 11 in the left square, row 2.
4. Fill in number 10 in the right square, row 3.
5. Fill in number 8 in the second from right square, row 4.
6. Using the rest of the numbers from 1 to 16, and never using a number more than once, make a magic square.

Observations

Here is a hint if you need one. Each column and diagonal will add up to 34.

EXPERIMENT 3

Steps

1. Draw a square divided into five rows of five squares each.
2. Using the numbers 1 to 25, make your own magic square.

Observations

In working out these squares, we first determined what each column and diagonal should add up to. For the 3-by-3 square we added 1 through 9 and divided by 3 to get 15. For the 4-by-4 square we added 1 through 16 and divided by 4 to get 34.

■ COMPUTER ARITHMETIC

Purpose

All the numbers in our numerical system can be expressed by ten symbols—nine digits and a zero. But a number system based on ten is just one of many possibilities. Computers use a system based on two, called the binary system, which involves only the symbols 0 and 1. All numbers can be expressed by these two symbols. The following experiments will introduce you to binary numbers.

Apparatus

pencil and paper

EXPERIMENT 1

Steps

1. Write the symbols 11111 on a piece of paper, Reading from right to left, this is what they represent: The first column represents 2^0, which is 1. The second column represents 2^1, which is 2. The third column represents 2^2, which is 4. The fourth column represents 2^3, which is 8. The fifth column represents 2^4, which is 16. Add $1 + 2 + 4 + 8 + 16$, and your result will be the number represented by the binary symbols 11111.

2. The symbol 1 indicates the presence of a power of two. The location of the 1 tells which power of two is present. If a power of two is not present, the symbol 0 appears in the proper place. Write 10010. Read from right to left. There is no power of two in the first column. The second column represents 2. There is no power of two in the third column, or in the fourth. In the fifth column 16 is represented. Thus 10010 stands for the number $2 + 16$, which is 18.

3. In the binary system the numbers 1, 2, 3, 4, and 5 are written 1, 10, 11, 100, 101. Study steps 1 and 2 and see if you can understand why. Now write the numbers 6 to 10 in binary.

4. Remember that any number can be written in the binary system. What does 101101110 represent?

5. To prove that you understand binary numbers, write 533 in binary.

Observations

Here are the answers to 3, 4, and 5. In binary the numbers 6 to 10 are written 110, 111, 1000, 1001 and 1010. The binary number 101101110 represents 366. (Remember how we got this? There is no 2^0. There is a 2^1, which is 2; a 2^2, which is 4; a 2^3, which is 8. There is no 2^4. There is a 2^5, which is 32; and a 2^6, which is 64. There is no 2^7. There is a 2^8, which is 256. Add up the powers that are represented, and you will have 366.) Step 5 asks you to write 533 using only 1's and 0's. This number written in binary is 1000010101.

EXPERIMENT 2

Steps

1. Make two columns on a piece of paper. Put the number 85 in the left column and the number 37 in the right. We are going to show you an odd-looking method of multiplying these two numbers together, based on the binary system.

2. Divide 85 by 2. Your result will be 42½. Ignore the fraction and list 42 under 85. Divide 42 by 2 and list your result. Continue dividing (always ignoring the fractions) and list your results until you have reached 1. Your left column will look like this:

85
42 (ignore the fraction)
21
10 (ignore the fraction)
5
2 (ignore the fraction)
1

3. Now go to work on the right column. Multiply 37 by 2 and list the result (74) under the 37. Multiply 74 by 2 and

list. Continue until you have multiplied by 2 as many times as you divided by 2 in the left column. The two columns together look like this:

85	37
42	74
21	148
10	296
5	592
2	1184
1	2368

4. Cross off all the even numbers in the left column (42, 10, and 2) and all the corresponding numbers in the right column (74, 296, and 1184). Forget about the left column and add up the remaining numbers in the right column. These will be:

37
148
592
2368

5. Multiply 85 by 37 the regular way and compare it with your answer in 4. They should be identical.

6. This system, sometimes called peasant multiplication, can be used to multiply any two sets of numbers. Try it out on any numbers you wish and test your results by multiplying the same numbers in the conventional way.

Observations

The reason why peasant multiplication works can be explained by the binary system. Let's go back to 85 times 37. What you are actually doing is changing 85 to binary form, multiplying each power of two that is present by 37 and adding the results. You convert 85 to a binary number by dividing down by 2. When your result is an odd number, place a 1 beside it. When your result is an even number, place a 0 beside it. Thus:

85	1
42	0
21	1
10	0
5	1
2	0
1	1

Reading from bottom to top you have the binary representation of 85—1010101. Now multiply 37 by each of the powers that are present:

2^0 times 37 is 37
there is no 2^1
2^2 times 37 is 148
there is no 2^3
2^4 times 37 is 592
there is no 2^5
2^6 times 37 is 2368

Now total the products. 3145

ALGEBRA

■ ALGEBRA WHEELS

Purpose

Spin a pointer and see where it stops on a numbered cardboard disk. Spin it again, and another pair of numbers will come up. Build four simple algebra wheels, set the pointers spinning, and work out the equations for which each wheel was designed.

Apparatus

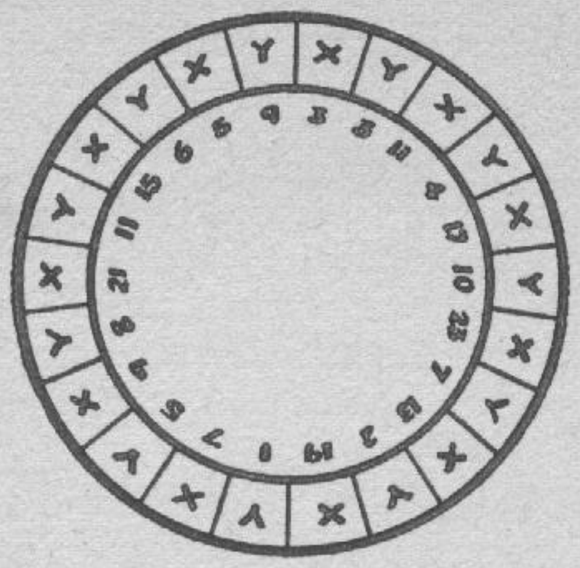
4 pieces of cardboard, about 6 inches square
4 drinking straws
4 thumbtacks
compass
pencil
scissors

Experiment 1

Steps

1. Use your compass to make a circle 6 inches in diameter on a piece of cardboard. Cut it out.

2. Make another circle, 5 inches in diameter, within the first circle. Do not cut.



3. In the space between the two circumferences mark off 22 equal divisions. Label the first x, the second y, the third x, etc., alternating x's and y's all around the wheel.

4. Just inside the inner circumference, mark off numbers all around the wheel. The first number should go directly under an x (any x) and the numbers follow clockwise in the order given here:

x	y	x	y	x	y	x	y	x	y	x	y
3	3	11	4	17	10	23	7	13	2	19	1

x	y	x	y	x	y	x	y	x	y
7	5	9	8	21	11	15	6	5	9

5. Cut one of the straws to 4 inches in length. Push a tack through the middle of it and attach it to the center of the wheel. It should spin easily.

6. If you have marked your wheel correctly, the spins of the pointer will show the following combinations:

when x is:	7	11	9	17	21	23	15	13	5	19	3
y is:	3	5	4	8	10	11	7	6	2	9	1

7. What does x equal in terms of y?

Experiments 2, 3, and 4

Steps

1. Follow steps 1, 2, and 3 of Experiment 1, using the three remaining pieces of cardboard to make your wheels.

2. Mark off numbers as described in step 4 of Experiment 1, but use the following three combinations:

Wheel 2:

x	y	x	y	x	y	x	y	x	y	x	y
2	7	6	3	4	9	10	14	3	10	9	4

x	y	x	y	x	y	x	y	x	y
5	8	1	6	7	12	12	5	8	11

Wheel 3:

x	y	x	y	x	y	x	y	x	y	x	y
7	6	16	9	37	2	13	5	28	7	34	1

x	y	x	y	x	y	x	y	x	y
22	4	31	11	10	3	19	8	25	10

Wheel 4:

x	y	x	y	x	y	x	y	x	y	x	y
4	7	7½	6	6	12	2½	3	4½	2	6½	4

x	y	x	y	x	y	x	y	x	y
5½	11	5	8	8	1	3½	5	3	9

3. Attach straw pointers as directed in step 5 of Experiment 1.

4. What does x equal for Wheel 2, for Wheel 3, for Wheel 4?

Observations

The answer to x will always be in terms of y. After you have worked out the four answers, check with these:

Wheel 1: $x = 2y + 1$
Wheel 2: $x = y - 2$
Wheel 3: $x = 3y + 4$
Wheel 4: $x = \dfrac{y + 4}{2}$

You can devise other algebra wheels (with less than 22 numbers if you're lazy). Try a 16-number wheel for the equation $x = 5y - 8$. Try an 18-number wheel for the equation $x = \dfrac{2y + 3}{4}$. Work out your own equations, make wheels for them and try them on your friends.

■ THINK OF A NUMBER

Purpose

Think of a Number is an old game in which player 1 picks a number and then adds, subtracts, multiplies, and divides as directed by player 2. At the end of all this arithmetic—without knowing the initial number—player 2 can astound player 1 by telling him the number he has ended up with. This is not done with a crystal ball, but with algebra. For, as the following problems will show, a meaningful relationship among a group of numbers can be written as an algebraic equation.

Apparatus

pencil and paper
clear head

Experiment 1

Steps

1. Think of a number.
2. Double it.
3. Add 10.
4. Divide by 2.
5. Subtract the number you started with.

Observations

No matter what number you started with, your answer is 5.

The equation for this problem is $\frac{2x + 10}{2} - x = 5$.

Experiment 2

Steps

1. Think of a number.
2. Multiply by 4.
3. Add 18.
4. Divide by 2.
5. Subtract 7.
6. Multiply by 3.

7. Divide by 6.
8. Subtract the number you started with.
9. Your answer is 1. Can you work out the equation?

Observations

The equation for this problem is $\frac{3\left(\frac{4x + 18}{2} - 7\right)}{6} - x = 1$

Experiment 3

Steps

1. Think of a number.
2. Triple it.
3. Add 21.
4. Subtract 9.
5. Divide by 3.
6. Multiply by 4.
7. Divide by 8.
8. Subtract half the number you started with.
9. Your answer is 2. Can you work out the equation?

Observations

The equation for this problem is $\frac{4\left(\frac{3x + 21 - 9}{3}\right)}{8} - \frac{1}{2}x = 2.$

Experiment 4

Note: Here is a variation on Think of a Number involving two unknowns.

Steps

1. Take your age (10 or over).
2. Double it.
3. Subtract 5.
4. Multiply by 50.
5. Add 265.

6. Add any number from 10 to 99.

7. Subtract 15.

8. You now have a four digit number. The first two digits will be your age; the last two will be the number from 10 to 99 that you added in step 6. Using x for the first unknown and y for the second, see if you can work out the equation for this problem.

Observations

The equation is $50\,(2x-5)+265+y-15=100x+y$.

■ ALGEBRA PUZZLES

Purpose

Here are five puzzles, each requiring the use of more than one equation for its solution. You may be tempted to guess at the answers, and perhaps you'll come up with the correct ones. But we recommend solving these puzzles the algebra way—it's more fun.

Apparatus

paper and pencil
clear head

Problems

1. Both of us have some books. Give me one of yours and then I'll have twice as many as you'll have. Or take one of mine and then we'll both have the same amount. How many books do you have? How many books have I?

2. Here is a basket of apples and bananas. If I buy three more apples and eat five bananas, there will be an equal amount of each fruit in the basket. Or if I double the number of apples I have now, I'll have three more apples than bananas. How many apples and bananas do I have?

3. Three cats are sunning themselves on the window sill. Daphne weighs twice as much as Alison, plus ½ pound. Pere weighs 1¾ pounds less than Alison, and is only ⅓ the size of Daphne. What does each cat weigh?

4. Julie's age is Danny's age minus Polly's. Katie is 4 years younger than Julie. Polly is 3 times as old as Katie and 2 years older than Julie. How old are Danny, Polly, Katie, and Julie?

5. If B is 6 times A, and C is ½ B; if D is 3 more than E and 13 less than G; if F is B plus D, and also G minus D; if A is 1/20 G, what are A, B, C, D, E, F, G?

Observations

By putting the given information in terms of algebraic equations, you can find the answers to these puzzles. You can make sure your answers are correct by going back to the puzzles and testing them out. Here is how we did them:

1. Call my books x and your books y.
$x+1$ (my books plus one of yours) $=2(y-1)$
(twice your books less the one you gave to me)
$x-1$ (my books less one I gave to you) $=y+1$
(your books plus one of mine)
if $x-1=y+1$, then $x=y+2$
if $x+1=2(y-1)$, then $x+1=2y-2$
$y+2+1=2y-2$
$y+3=2y-2$
therefore: $y=5$ $\quad x=7$

2. Call apples a, and bananas b.
given: $a+3=b-5 \quad 2a=b+3$
therefore: $a=b-8 \quad 2(b-8)=b+3 \quad 2b-16=b+3$
$b=19 \quad a=11$

3. Call Daphne d, Alison a, Pere p.
given: $d=2a+\frac{1}{2} \quad p=a-1\frac{3}{4} \quad p=\frac{1}{3}d$
therefore: $d=3p \quad 3p=2a+\frac{1}{2} \quad 3(a-1\frac{3}{4})=2a+\frac{1}{2}$
$3a-5\frac{1}{4}=2a+\frac{1}{2} \quad a=5\frac{3}{4} \quad p=4 \quad d=12$

4. Call Danny d, Julie j, Polly p, Katie k.
given: $j=d-p \quad k=j-4 \quad p=3k \quad p=j+2$
therefore: $3k=j+2 \quad k=\dfrac{j+2}{3} \quad \dfrac{j+2}{3}=j-4$
$j+2=3j-12 \quad 2j=14 \quad j=7 \quad k=3$
$p=9 \quad d=16$

5. given: $B=6A \quad C=\frac{1}{2}B \quad D=E+3 \quad D=G-13$
$F=B+D \quad F=G-D \quad A=\frac{1}{20}G$ or $G=20A$
therefore: $D=20A-13 \quad F=20A-(20A-13) \quad F=13$
$B+D=13 \quad 6A+20A-13=13 \quad 26A=26$
$A=1 \quad B=6 \quad C=3 \quad D=7 \quad E=4 \quad G=20$

GEOMETRY

■ FIGURES OF GEOMETRY

Purpose

Can you identify the figures of geometry? We'll tell you how to construct eight shapes and we'll give you eight names. See if you are able to match them up.

Apparatus

pencil and paper
protractor
ruler
compass

Steps

First make the figures.

1. Construct a figure with all sides equal.
2. Construct a parallelogram with four equal sides.
3. Construct a triangle with two equal sides.
4. Construct a five-sided figure.
5. Construct a parallelogram with four right angles.
6. Construct a triangle with no equal sides.
7. Construct a four-sided figure with one set of parallel sides.
8. Construct a figure which at every point is the same distance from its center.

Now match the figures with these names.

9. isosceles triangle
10. rectangle
11. trapezoid
12. equilateral polygon
13. circle
14. scalene triangle
15. pentagon
16. rhombus

Observations

Here are the correct combinations: 1 and 12; 2 and 16; 3 and 9; 4 and 15; 5 and 10; 6 and 14; 7 and 11; 8 and 13.

■ THE CIRCLE

Purpose

It is said that there are no perfect circles in nature; they are man's own invention. The experiments below will show you how to construct original circles and will demonstrate some interesting facts about this fundamental geometric form.

Apparatus

2 pieces of red paper, 7 inches square
2 pieces of blue paper, 7 inches square
2 pieces of yellow paper, 7 inches square
drawing board
tack
straight pin
piece of string, about 8 inches long
pencil
scissors
ruler
compass
protractor

Experiment 1

Steps

1. Tack a piece of the red paper (in its center) to the drawing board.
2. Hook one end of the string around the tack; tie the other end to the pencil. When the string is attached, its length from tack to pencil should be no more than 3 inches.
3. Holding the string taut, let the pencil rotate around the tack. When the pencil returns to its starting point, you will have a perfect circle.
4. Using the same technique, make a circle on the other piece of red paper. It should be identical to the first.
5. Snip ½ inch from the string and make two identical circles on the blue papers.

6. Snip another ½ inch from the string and make two identical circles on the yellow papers.

7. Cut out your six original circles.

EXPERIMENT 2

Steps

1. Fold a red circle in half, then in quarters. Unfold. Push the straight pin through the point where the folds intersect. This is the center of your circle.

2. Fold down the second red circle so that a chord is formed. Fold down another part of the circle and make a second chord. Bisect each chord with a perpendicular line and push the straight pin through the point where these lines intersect.

3. Place the second circle on top of the first so that the pin holes match. You will find that the second circle covers the first circle completely.

4. What do you conclude about the position of the hole in the second circle?

EXPERIMENT 3

Steps

1. Fold a blue circle in half and cut, making two semicircles.

2. Label the diameter of the first semicircle AB.

3. Fold a chord that is connected at one end to A. Label its other end C.

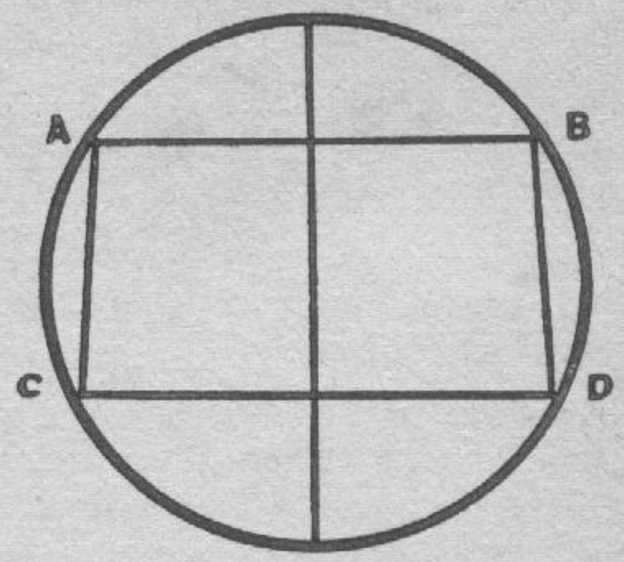
4. Connect B and C.

5. Repeat the same procedure on the other semicircle, but make the chord AC shorter or longer than the chord in the first semicircle.

6. Use a yellow circle to inscribe two other angles in semicircles, again varying the length of chord AC.

7. Measure the angle ACB in each semicircle. Does the length of the chord change the size of the angle? Does the size of the circle change the size of the angle?

EXPERIMENT 4



Steps

1. Fold a yellow circle in half to make a diameter. Unfold.

2. Fold two lines, AB and CD, perpendicular to the diameter, thus forming two parallel chords.

3. Fold a chord AC; fold a chord BD.

4. Cut out the four-sided figure you have formed and measure AC against BD.

5. Repeat steps 1 and 2 with the remaining blue circle, but make the lines AB and CD longer or shorter. Repeat steps 3 and 4.

6. What is the relationship of AB to CD?

Observations

Make larger circles, smaller circles, orange circles, purple circles, and try these experiments. You will find that the geometric laws which they demonstrate are constant, no matter the size of the circle. Perpendicular lines bisecting chords will always intercept at a circle's center; the only angle you can inscribe in a semicircle is a 90° angle; the lines that connect parallel chords will always be equal.

■ THE TRIHEXAFLEXAGON

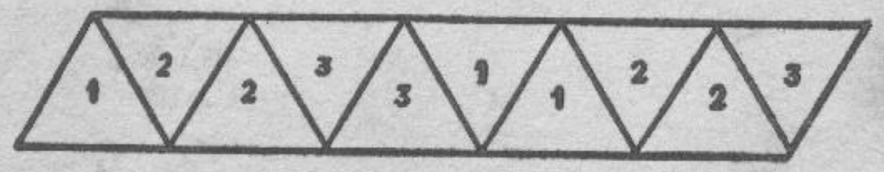
Problems

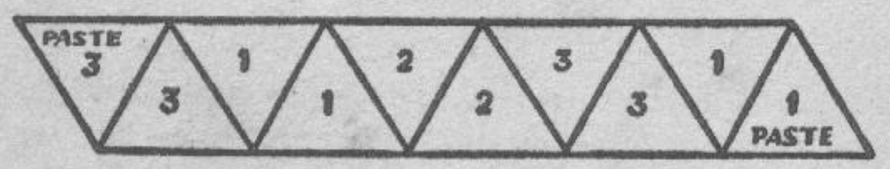
A hexagon is a six-sided figure. A regular hexagon is a figure whose six sides and six angles are equal. Six equilateral triangles make up a regular hexagon, but 18 equilaterals are

displayed by the trihexaflexagon, a geometric structure that has the ability to flex in most interesting ways. Below are instructions for constructing and operating a trihexaflexagon.

Apparatus

strip of paper, 2½ inches wide and 20 or more inches long
compass
protractor
ruler
blue crayon
red crayon
glue
scissors





Steps

First construct your trihexaflexagon.

1. Make an equilateral triangle on the paper strip, close to the left end. The lower edge of the strip should form the base of the triangle, and the apex should be a point on the upper edge. Call the points that form the base *x* and *y;* call the apex *z*. Cut off the excess paper to the left of the triangle only.

2. Make a second equilateral triangle by folding along line *yz* and bringing point *x* to the upper edge of the strip. (The apex of this triangle will be on the lower edge.) Use this technique to make a chain of ten triangles along the strip. Cut off the excess paper to the right of your final triangle.

3. Reverse all the creases between the triangles to keep your flexagon flexible.

4. Lay the triangle chain flat on a table. The front side should be numbered in the center of each triangle and lettered in the angles of the triangles as follows:

	number	letter
first triangle (apex up)	1	*a*—lower right angle
second triangle	2	*a*—apex angle
third triangle	2	*a*—lower left angle
		d—lower right angle
fourth triangle	3	*d*—apex angle
fifth triangle	3	*d*—lower left angle
		g—lower right angle
sixth triangle	1	*b*—apex angle
		c—upper right angle
seventh triangle	1	*c*—apex angle
		b—lower left angle
eighth triangle	2	*e*—apex angle
		c—upper left angle
		f—upper right angle
ninth triangle	2	*f*—apex angle
		e—lower left angle
tenth triangle	3	*h*—apex angle
		f—upper left angle
		a—upper right angle

5. Turn the chain on its unmarked side, so that the first triangle is the same as in step 4, except that its apex is pointing down. Number and letter the back of the chain as follows:

	number	letter
first triangle (apex down)	3	none
second triangle	3	*a*—apex angle
		h—lower left angle
third triangle	1	*a*—upper left angle
		d—upper right angle
fourth triangle	1	*d*—apex angle
fifth triangle	2	*d*—upper left angle
		g—upper right angle
sixth triangle	2	*g*—apex angle
		c—lower right angle
seventh triangle	3	*g*—upper left angle
eighth triangle	3	*f*—lower right angle
ninth triangle	1	none
tenth triangle	1	none

6. Fold each pair of adjacent 2's together, face to face. You now have a hexagon with triangles labeled 1 appearing on one side and triangles labeled 3 appearing on the other.

The tenth triangle overlaps the first and should be pasted to it. (Be sure to paste together the *unlettered* sides.)

7. Lightly color the triangles labeled 1 with your blue crayon. Lightly color the triangles labeled 3 with your red crayon.

Now you are ready to operate your trihexaflexagon:

8. Hold the trihexaflexagon with the blue face on top. Fold the blue corner labeled *aa,* bringing together the back red triangles also labeled *aa*. Push in the blue corner labelled *bb* and pull out the blue corner labeled *cc*. The hexagon will open up flat with its white face, labeled 2 on every triangle, on top. The process of opening the flexagon to show a new face is called a flexion.

9. Fold the white corner *dd,* bringing together the back blue triangles also labeled *dd*. Push in the white corner *ee* and pull out the white corner *ff*. The flexagon will open up flat with its red face showing.

10. To turn up the blue face again, fold the red *gg,* bringing together the white *gg*. Push in the red *hh* and pull out the red *aa*.

Observations

There are other ways to make the trihexaflexagon show its three faces. Experiment by flexing it at other corners. You will find that sometimes the flexagon won't open on top—this means that the flexion is blocked. But don't give up. Try another corner; you will find an unblocked flexion and you can keep flexing your trihexaflexagon indefinitely.

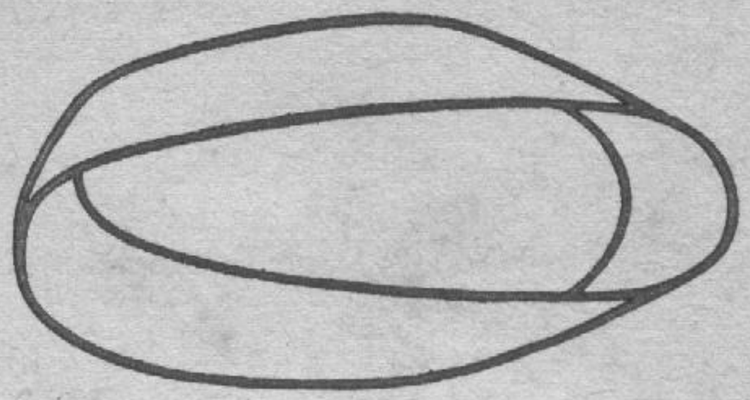
■ THE MOEBIUS STRIP

Purpose

When does a strip of paper have only one edge and one surface? You can see for yourself, by making a Moebius strip. To pronounce the word, by the way, say *mur-bius,* but go easy on the *r*.

Apparatus

strip of paper, 1 inch wide and 1 foot long
glue
crayon
scissors



Steps

1. Hold the strip in your hand and study it. You will find it to be a perfectly ordinary strip, with a front and a back.

2. Give the strip a half twist and glue the ends together. You now have a Moebius strip, which is not an ordinary strip at all.

3. Place the crayon at any point on the edge of the strip and run it along the edge until you come back to where you started. You will find that no part of the edge remains uncrayoned.

4. Place the crayon at any point on the surface of the strip and draw a line lengthwise until you return to your starting point. No part of the surface will remain unmarked.

5. Cut lengthwise down the center of your Moebius strip. When you return to your starting point you will have in your hand *one* strip still. It will be double the length and half the width of the original.

Observations

The Moebius strip study belongs to a special branch of geometry called topology, which studies the properties of geometrical figures that do not change, even when the figures are twisted, stretched, or otherwise deformed without tearing. In the world of topology, yesterday's square is today's circle, and distances are not to be counted on. You can't even trust a Moebius strip, in fact. Try cutting lengthwise down the center of a strip after giving it a *full* twist. Can you predict the result?

MEASUREMENT

■ MEASURING WITH TRIANGLES

Purpose

The following three problems in measurement can be solved without any measuring whatsoever, if you know a few simple facts about triangles. See if you can find the answers, using only pencil and paper.

Apparatus

pencil and paper
ruler—just for checking answers
protractor—just for checking answers

Problems

1. Jody is standing 4 feet from the base of a 9-foot wall that is perpendicular to the ground. She is staring at a point ⅔ from the top of the wall. What is the distance from that point to the place where she is standing?

2. My house is 8½ feet from a birdbath, which is an unknown distance from an apple tree. The house (H), bath (B) and tree (T) form a triangle whose angle HBT measures 74°. The angle BTH is 53°. What is the distance from the birdbath to the apple tree?

3. A flagpole stands at an equal distance from a hotel and a museum. The three points form a triangle whose angle HFM is 60°. If half the distance from hotel to museum is 1½ miles, how far is the flagpole from the two buildings?

Observations

If you can't solve these problems, go back and try again, keeping in mind that (a) in a right triangle the square on the hypotenuse equals the sum of the squares on the other two sides; (b) the sum of a triangle's angles must always be 180°; (c) a triangle with three equal angles must have three equal sides; (d) if a triangle has two equal angles, the sides opposite these angles must also be equal. If you think you have the correct answers now, use your ruler and protractor to draw the triangles and check their measurements.

■ MEASURING OFF A LINE

Purpose

Suppose you have a line which is 4⅞ inches long. Suppose you must divide this line into 19 equal parts. Now it is much easier to divide a 19-inch line or a 9½-inch line into 19 equal parts than it is to grapple with a line of 4⅞ inches. Here is how you can arrive at the difficult measurement by doing the easy one.

Apparatus

pencil and paper
ruler
protractor

Steps

1. Use the ruler to draw your 4⅞-inch line. Call it XY.

2. At any angle to XY draw a line XZ. Make it 19 inches long, or 9½ inches long.

3. You can easily measure off 19 equal parts on XZ. If you are using the 19-inch line, simply place your ruler along XZ and put a dot at each inch mark. For the 9½-inch line put a dot at each ½-inch point.

4. Connect point Z (your final division mark) to point Y.

5. Now draw lines from each marked-off point on line XZ to the undivided XY. Make the lines parallel to YZ.

6. The points at which your parallel lines cross line XY will divide XY into 19 equal parts. You can verify this with your ruler.

Observations

Any line can be measured off into any number of equal divisions by this same method. If parallel lines cut off equal segments of one line, they will cut off equal segments of another.

■ MEASURING WEIGHT

Purpose

Weighing by balancing probably goes back to cave-dweller days, when a man first decided which of two stones was heavier by hefting one in each hand. Since that time a

variety of balances have been devised. The experiments below will show you how to construct three weighing devices based on balance—a simple beam balance, a length-weight balance, and a spring balance.

Experiment 1

Apparatus

2 soda straws
3 straight pins
3 pieces of string, 2 equal in length, 1 longer
2 paper cups
salt
ruler
pencil

Steps

1. Measure in ¼ inch from each end of each straw. Mark these points with an X.

2. Find the point midway between the X's and mark this point Y on each straw.

3. Connect the straws side by side by inserting straight pins through each set of points X and through points Y. Separate the straws ¼ inch.

4. Tie the longer string to the center pin and suspend your balance by the other end of the string from a table or shelf edge. The straws should hang level. If they tilt at one end, adjust the pins until you achieve a perfect balance.

5. Attach the equal pieces of string to the paper cups and hang one from each end pin. Adjust your balance again if necessary until the cups are in equilibrium.

6. Pour salt in each cup until the cups are balanced. The cups of salt are equal in weight.

7. Pour ½ ounce of salt in one cup and add salt to the other until the cups are balanced.

Observations

The beam balance you have constructed can show whether materials are equal in weight. If they are not, you can learn which is the heavier material simply by looking at the balance. If you add a known weight to one of the cups, you can measure out an equal weight of a material in the other.

Experiment 2

Apparatus

12-inch ruler
3 pieces of thread, 2 equal in length, 1 longer
box of paper clips
drill
knife

Steps

1. Drill a hole at the 6-inch mark of the ruler, close to the upper edge.

2. Make notches above all the inch marks on the ruler, except the 6 and the 12.

3. Tie the longer thread through the hole and suspend the ruler from a shelf or table edge.

4. Tie the shorter threads into equal loops and loop one over the 1-inch notch, the other over the 11-inch notch.

5. Hang two paper clips from each loop. The ruler should be in balance.

6. Move one loop to the 3-inch notch; move the other to the 8-inch notch. The ruler will be unbalanced. Add a third paper clip to the loop at 8 inches to balance the ruler.

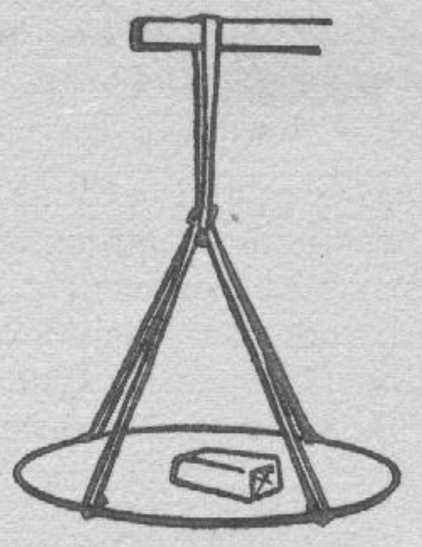
7. Add a clip to the right loop to make a total of 4 clips and move it to the 7-inch notch. Balance the ruler by moving the left loop to the 4-inch notch.

8. Move the right loop to the 10-inch notch and add two clips for a total of six. How many clips must hang from the loop at the 4-inch notch to make the ruler balance?

Observations

The ruler will balance if the units of weight times the units of length are equal for each side of the ruler. When six clips are hung 4 inches from the center (at the 10-inch notch) the units of weight times units of length equal 6×4 or 24. Thus the number of clips hung 2 inches from center (at the 4-inch notch) must be 12.

Experiment 3



Apparatus

piece of wood, 30 inches high, thick enough to stand by itself
strip of wood, 6 inches long, ½ inch wide
hammer and nails
scissors
piece of heavy cardboard, 8 inches square
piece of string, 48 inches long
rubber band (the "spring" of your scale)
4 4-ounce weights (A pound of butter divided into four sections makes good weights. Assure your mother that the butter will be returned to her in usable condition.)

Steps

1. Make a weighing pan by cutting a circle 6 inches in diameter from the cardboard. Punch four equidistant holes round the circle, near its circumference.

2. Cut the string in four equal pieces. Tie one end of each string to the holes. Tie the other ends together, hooking them over one end of the rubber band.

3. Make a holder for your weighing pan by hammering the smaller strip of wood to the larger one. The smaller strip should be placed at right angles to the larger, at or near the top, and should extend horizontally to the right or left at least 4½ inches.

4. Hang your weighing pan by its rubber band to the holder. The pan should hang free.

5. Place a 4-ounce weight on the pan. The rubber band will extend, thus lowering the pan. Mark the vertical piece of wood at the 4-ounce point.

6. Add the second 4-ounce weight and mark the wood at 8 ounces. Add the third weight and mark at 12 ounces; add the fourth and mark at 1 pound.

7. Cut one of the quarter-pound sections of butter in half. Place a 2-ounce weight in the weighing pan and mark the wood at 2 ounces. Combine this weight with 4 ounces, 8 ounces, and 12 ounces and mark their locations (6, 10, and 14 ounces) on the wood. The spring scale can now be used to determine the weight of objects between 2 ounces and 1 pound.

Observations

When an object is weighed with a spring balance, the earth's gravitational attraction for the object stretches the spring. At the point where the opposing force set up by the stretched spring equals the earth's pull on the object, the stretching stops. But gravitational pull varies—it is less strong on a mountain top than at sea level. Thus the spring scale would register one weight for an object on Mount Washington and another weight for that same object in Atlantic City. (Beam balances are not subject to this inaccuracy. Can you figure out why?)

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LAWS OF MATTER UP TO DATE

1. A single ATOM is the tiniest particle of any chemical element that can exist by itself and retain the qualities that mark it as that element.

2. All material things in the universe known to our senses are composed of atoms of CHEMICAL ELEMENTS.

3. Substances composed of more than one element are known as COMPOUNDS. Atoms attract and hold each other by electrical forces.

4. The smallest theoretical unit of a compound, composed of two or more atoms, is known as a MOLECULE; some elements are also normally found as molecules or crystals.

5. The smallest actual units of crystalline compounds found by use of microscopes and electron microscopes seem to be structures built up of the different atoms alternating in three-dimensional patterns to form the CRYSTAL LATTICE.

6. There were believed to be 92 CHEMICAL ELEMENTS, from hydrogen, $_{1}H^{1}$, the lightest, to uranium, $_{92}U^{238}$, the heaviest, before the discovery of nuclear fission.

7. Two new elements, NEPTUNIUM, $_{93}Np^{239}$, formed by the neutron bombardment of uranium 238, and PLUTONIUM, $_{94}Pu^{238}$, formed by deuteron bombardment of uranium 238, were discovered two years thereafter.

8. Additional new elements have since been created by atomic bombardment, using the cores of light elements as projectiles. As of 1961, elements through 103 have been added, the ones beyond plutonium being: AMERICIUM, CURIUM, BERKELIUM, CALIFORNIUM, EINSTEINIUM, FERMIUM, MENDELEVIUM, NOBELIUM (name in dispute), and LAWRENCIUM.

9. When elements are represented, as above, by their chemical symbols, the subscript number is the ATOMIC NUMBER. This is different for each element. The superscript number is the MASS NUMBER, and also the total number of protons plus neutrons, or the ATOMIC WEIGHT rounded off to the nearest whole number.

10. All atoms are composed of standard interchangeable parts. These are PROTONS, NEUTRONS and ELECTRONS.

11. Protons and neutrons make up the NUCLEUS of the atom. Collectively, they are called nucleons. The structure of the atom is comparable to that of the solar system, The nucleus corresponds to the sun at the center. The planets are electrons.

12. The ELECTRONS, light in weight and some distance away from the nucleus of the atom, revolve around the nucleus. They are held in their courses by electric attraction.

13. The proton has a POSITIVE charge of electricity, the electron has a NEGATIVE charge equal and opposite to the positive charge of the proton. The neutron has no charge at all.

14. The proton and the neutron each have a mass of about one ATOMIC MASS UNIT. Each is about 1800 times heavier than the electron.

15. ATOMIC NUMBER is the measure of the electric charge on, or number of protons in, the nucleus of the atom.

16. The difference in CHEMICAL PROPERTIES of the elements is caused by difference in the number of electrons, which in turn is caused by difference in the number of protons in the nucleus. The number of electrons and protons are equal in an electrically neutral atom.

17. Chemical VALENCE, or combining power, is governed primarily by the electrons in the outermost orbits of each atom. Characteristics of transition elements are also governed by electrons in the next-to-outermost shell.

18. MASS NUMBER is the total number of protons and neutrons in the nucleus.

19. ATOMIC WEIGHT is the measure of the atom's mass.

20. Different atoms of the SAME ELEMENT are sometimes found to have DIFFERENT ATOMIC WEIGHTS. Such atoms are called ISOTOPES.

21. In all other ways ISOTOPES are chemical twins, alike except for weight. They have the same ATOMIC NUMBER, but have different numbers of neutrons.

22. Every element has been found to have a number of isotopes, some STABLE, some RADIOACTIVE.

23. Atomic weights of individual ISOTOPES are usually given relative to the most abundant isotope of oxygen, ${}_{8}O^{16}$, taken as 16.00000 atomic mass units (physicists' scale).

24. There are two scales of ATOMIC WEIGHTS, physical and chemical. In the physical atomic weight scale, the mass of an atom of O^{16} is used as the standard and assigned a mass of 16.00000 units. In the chemical atomic weight scale, the atomic weight of the natural isotopic mixture of oxygen, which contains O^{16} and O^{18} in addition to O^{16}, is assigned the value of 16.00000.

25. Different elements, quite distinct in chemical behavior, may have isotopes of the same atomic weight. There are ${}_{92}U^{238}$, ${}_{93}Np^{238}$, ${}_{94}Pu^{238}$, ${}_{95}Am^{238}$ and ${}_{96}Cm^{238}$, all with different properties. Such atoms are called ISOBARS.

26. It is the NEUTRON which figures in the transmutations that give atomic power from uranium. Neutrons can PENETRATE to the nucleus of heavy atoms when charged particles would be repelled by charges in the atom. The neutron is absorbed by the nucleus to form a heavier nucleus that is frequently unstable. If it is unstable, it then decomposes radioactively, usually emitting an electron and changing to a different element one atomic number greater.

27. The HYDROGEN atom, ${}_{1}H^{1}$, has just one proton as its nucleus, with one electron circling around it. Hydrogen's atomic weight and atomic number are each one.

28. Hydrogen has a rare istotope, ${}_{1}H^{2}$, that is just like ordinary hydrogen except it is twice as heavy. It is known as "heavy hydrogen" and sometimes as DEUTERIUM (Symbol: D). Its compound with oxygen is called "heavy water."

29. The nucleus of DEUTERIUM, called a DEUTERON, contains one proton and one neutron. The atomic number of heavy hydrogen is one, corresponding to one proton. The atomic weight is two, corresponding to the two heavy particles, proton and neutron. A third form of hydrogen, the RADIOACTIVE isotope TRITIUM, ${}_{1}H^{3}$, is composed of one proton and two neutrons.

30. HELIUM, ${}_{2}He^{4}$, has two protons and two neutrons in its nucleus. The two protons correspond to helium's atomic number two. The combined weights of protons and neutrons in the nucleus give helium its atomic weight four. Two electrons, held in their orbits by the two protons, revolve around the nucleus.

31. Helium 4 at temperatures near absolute zero is a liquid with most remarkable properties and is the only known SUPERFLUID.

32. Helium also has a rare LIGHTER ISOTOPE, ${}_{2}He^{3}$, composed of two protons and one neutron.

33. Uranium has a number of isotopes. The most abundant, whose atomic weight is 238, was used to produce the new elements. U-235 was used to make the first ATOMIC BOMB.

34. The isotope U-235 and the element plutonium can be used for bombs because they are capable of FISSION after absorbing a neutron.

35. When fission occurs, the nucleus of the atom SPLITS into two (occasionally more) lighter elements, with release of nuclear energy.

36. In some recent experiments with high-powered cyclotrons, even more thorough fragmentation of atomic nuclei resulted. This process, resulting in many light elements, was named SPALLATION. General laws are now known that explain the processes by which atoms and nuclear particles unite and divide to form isotopes of particular mass, form and radioactive lifetimes.

37. FUSION, the process by which stars obtain their energy, is a nuclear reaction in which light nuclei combine to form a nucleus of a higher mass number, releasing large amounts of energy. The process can be said to be the opposite of nuclear fission. Fusion forms the basis of the hydrogen bomb. The possibility that the virtually limitless fuel locked as forms of hydrogen in the world's ocean can be tapped by the controlled release of fusion is under extensive investigation throughout the world.

38. MESONS are short-lived particles intermediate in mass between electrons and nucleons. HYPERONS are particles intermediate in mass between nucleons and deuterons. Their role in holding particles together in the atomic nucleus is being investigated.

39. The VOLUME of an atom is determined by the orbits of its outermost revolving electrons. Only a small fraction of the size of an atom is actually occupied by the protons, neutrons and electrons,

somewhat as the space occupied by the sun, the earth and other planets is only a small part of our solar system.

40. In spite of all the unoccupied space, an atom is quite IMPENETRABLE to other atoms and to larger bodies. The electrons revolve millions of times a second, and keep everything out of the space within quite as effectively as though they were everywhere at once.

41. The things that can get inside an atom easily are protons, neutrons or electrons and fragments of other atoms. They must be shot with sufficient SPEED.

42. RADIATION is wave motion, known to us as the electromagnetic waves used for radio transmission, heat, light, X-rays, gamma rays, and as beams of atomic particles. Extremely tiny particles act like waves.

43. Three types of rays are given off by radioactive substances. ALPHA particles are high-speed nuclei of helium atoms. BETA particles are high-speed electrons. GAMMA RAYS are electromagnetic radiations similar to X-rays and light.

44. Of these, only the gamma rays used to be called radiation, and even these act very much like particles because of their short wavelength. Such a "particle" or quantum of electromagnetic radiation is called a PHOTON.

45. All atoms, when excited by high temperatures or by electric discharge, may emit light rays. These light rays, sorted according to wavelength with spectrographs, make up the SPECTRA characteristic of the elements. Most of our information about the outer structure of atoms is derived from these spectra.

46. Electrically charged particles, such as electrons, may be bent out of their straight-line paths by the influence of a magnet. This principle is used in the construction of the CYCLOTRON.

47. POSITRONS are like electrons, but are bent in the opposite direction because their charges are positive instead of negative. Thus a positron is an "anti-electron."

48. Scientists now know that atomic particles as well as mesons and hyperons have so-called "anti" forms, which denote another particle with most of the same characteristics but differing in others, including charge and magnetic moment. When normal matter collides with ANTI-MATTER, both are annihilated and tremendous amounts of energy are released.

49. The kind of rays emitted and the HALF LIFE (the time in which half the radioactivity decays) are constant characteristics of each radioactive isotope, and are used to identify that isotope.

50. In general, the gamma rays are very PENETRATING, beta rays less so, and alpha particles are easily stopped. Even though the alpha and beta rays are not very penetrating, they have enormous speed.

51. ENERGY is capacity to do work. It is work stored up for future use.

52. If you raise a weight to a height above the ground and suspend it there by some device, the work you put into raising it can be stored there indefinitely as POTENTIAL ENERGY. It will be there, ready, whenever you decide to release it.

53. The energy that a moving body has because it is in motion is called KINETIC ENERGY. The kinetic energy of any particle depends upon its mass and its velocity. When the moving particle strikes an object, work is done.

54. Particles of atomic size have kinetic energy arising from several different kinds of MOTION. All atoms are constantly in motion.

55. If the atoms are so dispersed that the material constituting them is a GAS, that gas will exert pressure on all sides of the container holding it, because of the motion of the gas molecules.

56. Atoms composing an element that will combine readily with another element, as hydrogen or carbon will combine with oxygen, have incomplete arrangements of the outer electrons in their systems. These incomplete arrangements allow CHEMICAL COMBINATION to take place when elements with suitable combining powers are brought together.

57. When chemical reactions occur, energy can be absorbed or released in the process. Reactions in which energy is absorbed are called ENDOTHERMIC REACTIONS; those in which energy is released are called EXOTHERMIC REACTIONS.

58. Chemical energy, electricity and heat are all forms of ENERGY. Potential and kinetic energy may be distinguished in each case.

59. These energies all arise from motion of the atom as a whole, or motion resulting from attractions and repulsions between the outer ELECTRONS of the atom's structure.

60. Energy resulting from changes in the nucleus of the atom was unknown until the discovery of RADIOACTIVITY.

61. Radioactive isotopes undergo SPONTANEOUS breaking up of their nuclei, giving off beta, alpha or gamma radiation. Loss of these particles causes the radioactive isotopes to change into isotopes of other elements.

62. The energies shown in these TRANSMUTATIONS are millions of times greater than the kinetic energies the molecules of a gas have by reason of their motion when heated. They are about a million times greater than the energy changes per atom in chemical reactions.

63. The property of matter that connects it with motion is INERTIA. Inertia is resistance to change of motion and is the measure of the MASS of an object.

64. One conclusion that appeared early in the development of the theory of RELATIVITY is that the mass of a moving body increases as its speed is increased.

65. This increase implies an equivalence between an increase in energy of motion of a body (kinetic energy) and an increase in its MASS.

66. It is for this reason that Einstein suggested that studies of radioactivity might show the EQUIVALENCE of mass and energy.

67. Einstein's statement is that the amount of energy, E, equivalent to a mass, m, is given by the equation $E = mc^2$, where c is the VELOCITY OF LIGHT.

68. From this equation, one kilogram (2.2 pounds) of matter, if CONVERTED entirely into energy, would give 25 billion kilowatt hours of energy.

69. The heat produced by BURNING one kilogram of coal is 8.5 kilowatt hours of energy.

70. Two axioms of physics state: (1) MATTER can be neither created nor destroyed; (2) ENERGY can be neither created nor destroyed. For all practical purposes they were true and separate principles until about 1940.

71. It is now known that they are, in fact, TWO PHASES of a single principle, for we have discovered that energy may sometimes be converted into matter and matter into energy.

72. Such conversion is observed in the phenomenon of nuclear FISSION, a process in which atomic nuclei split into fragments with the release of an enormous amount of energy.

73. The extreme size of the CONVERSION FACTOR explains why the equivalence of mass and energy is never observed in ordinary chemical combustion.

74. We now believe the heat given off in chemical COMBUSTION has mass associated with it, but this mass is so small it cannot be detected by the most sensitive balances available.

75. From the standpoint of the Laws of the Conservation of Matter and of Energy alone, transformation of matter into energy results in the DESTRUCTION of matter and CREATION of energy.

(Compiled originally by Helen M. Davis; revised 1961.)

■ HOUSEHOLD CHEMICALS

Household Name	Chemical Name	Formula
ammonia water	ammonium hydroxide	NH_4OH
aspirin	acetylsalicylic acid	$C_6H_4(OCOCH_3)COOH$
baking soda	sodium bicarbonate	$NaHCO_3$
cane sugar	sucrose	$C_{12}H_{22}O_{11}$
chalk	calcium carbonate	$CaCO_3$
charcoal	wood carbon	C
dry ice	solid carbon dioxide	CO_2
Epsom salts	magnesium sulfate	$MgSO_4 \cdot 7H_2O$
lye	sodium hydroxide	NaOH
marble	calcium carbonate	$CaCO_3$
milk of magnesia	magnesium hydroxide	$Mg(OH)_2$
moth balls	naphthalene	$C_{10}H_8$
peroxide	hydrogen peroxide	H_2O_2
rouge	ferric oxide	Fe_2O_3
salt	sodium chloride	NaCl
sand	silicon dioxide	SiO_2
vinegar	dilute acetic acid	$HC_2H_3O_2$

■ THE PLANT KINGDOM

Subkingdom Thallophyta

Phylum	Class	Order	Description
Cyanophyta			algae
Euglenophyta			algae
Chlorophyta			algae
Chrysophyta			algae
Pyrrophyta			algae
Phaeophyta			algae
Rhodophyta			algae
Schizophyta			fungi
Eumycophyta			fungi
Myxomycophyta			fungi

Subkingdom Embryophyta

Phylum	Class	Order	Description
Bryophyta			
	Musci		mosses
	Hepaticae		liverworts
	Anthocerotae		hornworts
Tracheophyta			vascular plants

Subphylum	Class	Order	Description
Psilopsida			
	Psilophytineae		
		Psilophytales	fossils
		Psilotales	psilophytes
Lycopsida			club mosses
	Lycopodineae		
		Lycopodiales	club mosses
		Selaginellales	club mosses
		Lepidodendrales	fossils
		Pleuromeiales	fossils
		Isoetales	quillworts
Sphenopsida			horsetails
	Equisetineae		
		Hyeniales	fossils
		Sphenophyllales	fossils
		Equisetales	horsetails
Pteropsida			
	Filicineae		ferns
		Coenopteridales	fossils
		Ophioglossales	adder's tongue fern
		Marattiales	marattiaceous ferns
		Filicales	true ferns
	Gymnospermae		conifers and related plants
	Subclass		
	Cycadophytae		
		Cycadofilicales	fossils
		Bennettitales	fossils
		Cycadales	cycads
	Coniferophytae		
		Cordaitales	fossils
		Ginkgoales	ginko tree
		Coniferales	conifers
		Gnetales	**Ephedra, Gnetum, Welwitschia**
	Angiospermae		flowering plants
	Subclass		
	Dicotyledoneae		dicots
	Monocotyledoneae		monocots

■ THE ANIMAL KINGDOM

Subkingdom Protozoa—Single-celled Animals

Phylum	Class	Description
Protozoa		
	Flagellata	flagellates
	Sarcodina	rhizopods
	Sporozoa	sporozoans
	Ciliata	ciliates
	Suctoria	suctorians

Subkingdom Metazoa—Multi-celled Animals

Phylum	Class	Description
Mesozoa		mesozoans
Porifera		sponges
	Calcarea	calcareous sponges
	Hyalospongiae	glass sponges
	Demospongiae	horny or keratinous sponges
Coelenterata		coelenterates
	Hydrozoa	hydrozoans
	Scyphozoa	oceanic jellyfish
	Anthozoa	corals, sea anemones, sea fans, sea pens
Ctenophora		comb jellies
Platyhelminthes		flatworms
	Turbellaria	flatworms
	Trematoda	parasitic flukes
	Cestoda	parasitic tapeworms
Nemertina		nemertean worms
Nemathelminthes		roundworms
Rotifera		rotifers or wheel animalcules
Gastrotricha		gastrotrichs
Kinorhyncha		kinorhynchids
Nematomorpha		hair worms
Acanthocephala		thorny-headed worms
Entoprocta		moss animals
Priapulida		priapulids
Annelida		
	Polychaeta	polychaetes
	Oligochaeta	oligochaetes
	Hirudinea	leeches
Echiuroidea		echiurids
Sipunculoidea		peanut worms
Mollusca		mollusks
	Amphineura	chitons
	Scaphopoda	tooth shells
	Gastropoda	snails, slugs, limpets
	Pelecypoda	clams, oysters, mussels, shipworms
	Cephalopoda	squids, octopuses, nautiluses
Bryozoa		moss animals
Brachiopoda		lamp shells
Phoronida		phoronids
Arthropoda		arthropods
	Onychophora	onychophorans
	Crustacea	crustaceans
	Trilobita	fossils
	Meristomata	horseshoe crabs
	Arachnida	arachnids
	Diplopoda	millipedes
	Chilopoda	centipedes
	Insecta	insects

Phylum	Class	Description
Echinodermata		ectoderms
	Asteroidea	starfish
	Ophiuroidea	brittle stars
	Echinoidea	sea and heart urchins
	Holothuroidea	sea cucumber
	Crinoidea	sea lilies
Chaetognatha		arrow worms
Pogonophora		beard worms
Chordata		
Subphylum		
Hemichordata		tongue worms, acorn worms
Urochordata		tunicates
Cephalochordata		lancelets
Vertebrata		vertebrates
Superclass		
Pisces		
	Agnatha	lamprey eels, hag fishes
	Chondrichthyes	sharks, rays
	Osteichthyes	bony fish
Superclass		
Tetrapoda		
	Amphibia	frogs, salamanders, toads
	Reptilia	turtles, snakes, lizards, etc.
	Aves	birds
	Mammalia	mammals

■ RELATIVE HUMIDITY TABLE

Dry-bulb temperature	DIFFERENCE BETWEEN WET- AND DRY-BULB TEMPERATURES													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
98	96	93	89	86	82	79	76	72	69	66	63	60	57	54
96	96	93	89	85	82	78	75	72	68	65	62	59	57	54
94	96	93	89	85	81	78	75	71	68	65	62	59	56	53
92	96	92	88	85	81	78	74	71	67	64	61	58	55	52
90	96	92	88	84	81	77	74	70	67	63	60	57	54	51
88	96	92	88	84	80	77	73	69	66	63	59	56	53	50
86	96	92	88	84	80	76	72	69	65	62	58	55	52	49
84	96	92	87	83	79	76	72	68	64	61	57	54	51	47
82	96	91	87	83	79	75	71	67	64	60	56	53	49	46
80	96	91	87	83	79	74	70	66	63	59	55	52	48	45
78	95	91	86	82	78	74	70	66	62	58	54	50	47	43
76	95	91	86	82	78	73	69	65	61	57	53	49	45	42
74	95	90	86	81	77	72	68	64	60	56	52	48	44	40
72	95	90	85	80	76	71	67	63	58	54	50	46	42	38
70	95	90	85	80	75	71	66	62	57	53	49	44	40	36
68	95	90	84	79	75	70	65	60	56	51	47	43	38	34
66	95	89	84	79	74	69	64	59	54	50	45	41	36	32
64	94	89	83	78	73	68	63	58	53	48	43	39	34	30
62	94	88	83	77	72	67	61	56	51	46	41	37	32	27
60	94	88	82	77	71	65	60	55	50	44	39	34	29	25
58	94	88	82	76	70	64	59	53	48	42	37	31	26	22
56	94	87	81	75	69	63	57	51	46	40	35	29	24	19
54	93	87	80	74	68	61	55	49	43	38	32	26	21	15
52	93	86	79	73	66	60	54	47	41	35	29	23	17	12
50	93	86	79	72	65	59	52	45	38	32	26	20	14	8
48	92	85	77	70	63	56	49	42	36	29	22	16	10	4
46	92	84	77	69	62	54	47	40	33	26	19	12	6	—
44	92	84	75	68	60	52	45	37	29	22	15	8	—	—
42	91	83	74	66	58	50	42	34	26	18	—	—	—	—
40	91	82	73	65	56	47	39	30	—	—	—	—	—	—

This table is in degrees Fahrenheit.

■ CENTIGRADE TO FAHRENHEIT CONVERSION TABLE

°C	°F	°C	°F	°C	°F	°C	°F
0	32						
1	34	26	79	51	124	76	169
2	36	27	81	52	126	77	171
3	37	28	82	53	127	78	172
4	39	29	84	54	129	79	174
5	41	30	86	55	131	80	176
6	43	31	88	56	133	81	178
7	45	32	90	57	135	82	180
8	46	33	91	58	136	83	181
9	48	34	93	59	138	84	183
10	50	35	95	60	140	85	185
11	52	36	97	61	142	86	187
12	54	37	99	62	144	87	189
13	55	38	100	63	145	88	190
14	57	39	102	64	147	89	192
15	59	40	104	65	149	90	194
16	61	41	106	66	151	91	196
17	63	42	108	67	153	92	198
18	64	43	109	68	154	93	199
19	66	44	111	69	156	94	201
20	68	45	113	70	158	95	203
21	70	46	115	71	160	96	205
22	72	47	117	72	162	97	207
23	73	48	118	73	163	98	208
24	75	49	120	74	165	99	210
25	77	50	122	75	167	100	212

■ WEIGHTS AND MEASURES

LINEAR MEASURE

12 inches ..... 1 foot
3 feet ..... 1 yard
5280 feet ..... 1 mile

SQUARE MEASURE

144 square inches .... 1 square foot
9 square feet ..... 1 square yard
640 acres ..... 1 square mile

LIQUID MEASURE

4 gills ..... 1 pint
2 pints ..... 1 quart
4 quarts ..... 1 gallon

DRY MEASURE

2 pints ..... 1 quart
8 quarts ..... 1 peck
32 quarts ..... 1 bushel

The Metric System

LENGTH

10 millimeters ..... 1 centimeter
10 centimeters ..... 1 decimeter
10 decimeters ..... 1 meter
10 meters ..... 1 decameter
10 decameters ..... 1 hectometer
10 hectometers ..... 1 kilometer
10 kilometers ..... 1 myriameter

WEIGHT

10 milligrams ..... 1 centigram
10 centigrams ..... 1 decigram
10 decigrams ..... 1 gram
10 grams ..... 1 decagram
10 decagrams ..... 1 hectogram
10 hectograms ..... 1 kilogram
1000 kilograms ..... 1 metric ton

Conversions

1 Inch ..... 2.54 centimeters
1 foot ..... 30.48 centimeters
1 quart liquid ..... 0.9463 liter

1 centimeter ..... 0.3937 inch
1 meter ..... 39.37 inches
1 liter ..... 1.057 quarts liquid

■ TABLE OF SQUARES AND SQUARE ROOTS

N	N^2	$\sqrt{N}$	N	N^2	$\sqrt{N}$	N	N^2	$\sqrt{N}$
1	1	1.000	51	2 601	7.141	101	10 201	10.050
2	4	1.414	52	2 704	7.211	102	10 404	10.100
3	9	1.732	53	2 809	7.280	103	10 609	10.149
4	16	2.000	54	2 916	7.348	104	10 816	10.198
5	25	2.236	55	3 025	7.416	105	11 025	10.247
6	36	2.449	56	3 136	7.483	106	11 236	10.296
7	49	2.646	57	3 249	7.550	107	11 449	10.344
8	64	2.828	58	3 364	7.616	108	11 664	10.392
9	81	3.000	59	3 481	7.681	109	11 881	10.440
10	100	3.162	60	3 600	7.746	110	12 100	10.488
11	121	3.317	61	3 721	7.810	111	12 321	10.536
12	144	3.464	62	3 844	7.874	112	12 544	10.583
13	169	3.606	63	3 969	7.937	113	12 769	10.630
14	196	3.742	64	4 096	8.000	114	12 996	10.677
15	225	3.873	65	4 225	8.062	115	13 225	10.724
16	256	4.000	66	4 356	8.124	116	13 456	10.770
17	289	4.123	67	4 489	8.185	117	13 689	10.817
18	324	4.243	68	4 624	8.246	118	13 924	10.863
19	361	4.359	69	4 761	8.307	119	14 161	10.909
20	400	4.472	70	4 900	8.367	120	14 400	10.954
21	441	4.583	71	5 041	8.426	121	14 641	11.000
22	484	4.690	72	5 184	8.485	122	14 884	11.045
23	529	4.796	73	5 329	8.544	123	15 129	11.091
24	576	4.899	74	5 476	8.602	124	15 376	11.136
25	625	5.000	75	5 625	8.660	125	15 625	11.180
26	676	5.099	76	5 776	8.718	126	15 876	11.225
27	729	5.196	77	5 929	8.775	127	16 129	11.269
28	784	5.292	78	6 084	8.832	128	16 384	11.314
29	841	5.385	79	6 241	8.888	129	16 641	11.358
30	900	5.477	80	6 400	8.944	130	16 900	11.402
31	961	5.568	81	6 561	9.000	131	17 161	11.446
32	1 024	5.657	82	6 724	9.055	132	17 424	11.489
33	1 089	5.745	83	6 889	9.110	133	17 689	11.533
34	1 156	5.831	84	7 056	9.165	134	17 956	11.576
35	1 225	5.916	85	7 225	9.220	135	18 225	11.619
36	1 296	6.000	86	7 396	9.274	136	18 496	11.662
37	1 369	6.083	87	7 569	9.327	137	18 769	11.705
38	1 444	6.164	88	7 744	9.381	138	19 044	11.747
39	1 521	6.245	89	7 921	9.434	139	19 321	11.790
40	1 600	6.325	90	8 100	9.487	140	19 600	11.832
41	1 681	6.403	91	8 281	9.539	141	19 881	11.874
42	1 764	6.481	92	8 464	9.592	142	20 164	11.916
43	1 849	6.557	93	8 649	9.644	143	20 449	11.958
44	1 936	6.633	94	8 836	9.695	144	20 736	12.000
45	2 025	6.708	95	9 025	9.747	145	21 025	12.042
46	2 116	6.782	96	9 216	9.798	146	21 316	12.083
47	2 209	6.856	97	9 409	9.849	147	21 609	12.124
48	2 304	6.928	98	9 604	9.899	148	21 904	12.166
49	2 401	7.000	99	9 801	9.950	149	22 201	12.207
50	2 500	7.071	100	10 000	10.000	150	22 500	12.247

■ CHEMICAL ELEMENTS

Atomic weight is the average of an atom compared to an average atom of ordinary terrestrial oxygen as 16.

For the radioactive elements (with the exceptions of uranium, thorium, and radium), the mass number of either the isotope of longest half-life or the better known isotope (indicated with a star) is given.

Chemical element	Symbol	Atomic number	Atomic weight
Actinium	Ac	89	227
Aluminum	Al	13	26.98
Americium	Am	95	*243
Antimony	Sb	51	121.76
Argon	Ar	18	39.944
Arsenic	As	33	74.91
Astatine	At	85	210
Barium	Ba	56	137.36
Berkelium	Bk	97	*249
Beryllium	Be	4	9.013
Bismuth	Bi	83	209.00
Boron	B	5	10.82
Bromine	Br	35	79.916
Cadmium	Cd	48	112.41
Calcium	Ca	20	40.08
Californium	Cf	98	*249
Carbon	C	6	12.011
Cerium	Ce	58	140.13
Cesium	Cs	55	132.91
Chlorine	Cl	17	35.457
Chromium	Cr	24	52.01
Cobalt	Co	27	58.94
Copper	Cu	29	63.54
Curium	Cm	96	*247
Dysprosium	Dy	66	162.51
Einsteinium	E	99	*254
Element 102	.....	102	*254
Erbium	Er	68	167.27
Europium	Eu	63	152.0
Fermium	Fm	100	*255
Fluorine	F	9	19.00
Francium	Fr	87	*223
Gadolinium	Gd	64	157.26
Gallium	Ga	31	69.72
Germanium	Ge	32	72.60
Gold	Au	79	197.0
Hafnium	Hf	72	178.50
Helium	He	2	4.003
Holmium	Ho	67	164.94
Hydrogen	H	1	1.0080
Indium	In	49	114.82
Iodine	I	53	126.91
Iridium	Ir	77	192.2
Iron	Fe	26	55.85
Krypton	Kr	36	83.80

Chemical element	Symbol	Atomic number	Atomic weight
Lanthanum	La	57	138.92
Lawrencium	Lw	103	*257
Lead	Pb	82	207.21
Lithium	Li	3	6.940
Lutetium	Lu	71	174.99
Magnesium	Mg	12	24.32
Manganese	Mn	25	54.94
Mendelevium	Mv	101	*256
Mercury	Hg	80	200.61
Molybdenum	Mo	42	95.95
Neodymium	Nd	60	144.27
Neon	Ne	10	20.183
Neptunium	Np	93	*237
Nickel	Ni	28	58.71
Niobium†	Nb	41	92.91
Nitrogen	N	7	14.008
Osmium	Os	76	190.2
Oxygen	O	8	16.0000
Palladium	Pd	46	106.4
Phosphorus	P	15	30.975
Platinum	Pt	78	195.09
Plutonium	Pu	94	*242
Polonium	Po	84	*210
Potassium	K	19	39.100
Praseodymium	Pr	59	140.92
Promethium	Pm	61	*147
Protactinium	Pa	91	231
Radium	Ra	88	226.05
Radon	Rn	86	222
Rhenium	Re	75	186.22
Rhodium	Rh	45	102.91
Rubidium	Rb	37	85.48
Ruthenium	Ru	44	101.1
Samarium	Sm	62	150.35
Scandium	Sc	21	44.96
Selenium	Se	34	78.96
Silicon	Si	14	28.09
Silver	Ag	47	107.880
Sodium	Na	11	22.991
Strontium	Sr	38	87.63
Sulfur	S	16	32.006
Tantalum	Ta	73	180.95
Technetium	Tc	43	*99
Tellurium	Te	52	127.61
Terbium	Tb	65	158.93
Thallium	Tl	81	204.39
Thorium	Th	90	232.05
Thulium	Tm	69	168.94
Tin	Sn	50	118.70
Titanium	Tl	22	47.90

† formerly Columbium

ABOUT THE AUTHOR

JUDITH VIORST is a staff writer for Science Service. Among the many assignments that she has completed for them are two books, *Projects: Space,* and *Wonderful World of Science,* with Shirley Moore. Science Service, Inc., is the non-profit Institution for the Popularization of Science. Its many ambitious projects include the famous science fairs held throughout the country, the National Science Fair-International, and the Science Talent Search. Another service is the publication of the SCIENCE NEWS LETTER which enables students and the general public to keep up with the latest information on developments in science.